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Early locus of a linguistic variable in a fast priming task

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The syllable and the morpheme are known to be important linguistic variables, but is such information involved in the early stages of word recognition? Syllable-morpheme information was manipulated in the early stage of word naming by means of the fast priming paradigm. The letters in the prime were printed in a mixture of lower- and upper-case letters. The change from lower to upper case occurred either at a syllable-morpheme boundary, before the boundary, or after it (e.g., reTAKE, rETAKE, or retAKE) creating either an intact pair or a broken one. The target was always in lower case (e.g., retake). The results of Experiments 1 and 2 revealed that intact syllable and morpheme information facilitated word naming at a short Stimulus Onset Asynchrony (below awareness) but not at a long SOA, suggesting that the use of such information is automatic. A second set of experiments attempted to determine if syllable information alone could facilitate word processing. In Experiments 3 and 4, monomorphemic words were divided either at, before, or after the syllable boundary (e.g., rePEL, rEPEL, or repEL). The primes were all pseudomorphemic in the sense that the initial syllables could appear as a morpheme in other words (e.g., restate) but were not morphemic in the target words (e.g., repel). The second syllable was neither morphemic nor pseudomorphemic. Using the same SOAs as in Experiments 1 and 2, intact syllables were found to be facilitative at the short SOA, but not at the long SOA. Thus, the syllable plays a role in an early stage of word recognition. Whether morphemes that are not syllables are facilitative is still to be determined in this paradigm.

La syllabe et le morphème sont connus pour être d'importantes variables linguistiques, mais une telle information est-elle impliquée dans les étapes initiales de la reconnaissance des mots? On a manipulé l'information syllabe-morphème dans l'étape récente de nomination de mots à travers le paradigme de présentation rapide du stimulus primaire. Les lettres dans le stimulus primaire ont été imprimées avec un mélange de majuscules et de minuscules. Le changement de lettre minuscule à lettres majuscule avait lieu soit sur une ligne syllabe morphème avant la liaison ou après celle-ci (ex: reTAKE, rETAKE, ou retAKE), créant soit une paire intacte ou une paire brisée. L'objectif se présentait toujours en minuscules (ex: retake). Les résultats des expériences 1 et 2 ont révélé que l'information intacte de la syllabe et du morphème facilitait la nomination de mots quand la Asynchronisation de l'Initialisation du Stimulus (AIS) était courte, mais pas quand elle était longue. Cela suggère que l'utilisation d'une telle information est automatique. Un second groupe d'expériences a tenté de déterminer si l'information de la syllabe seule pourrait faciliter le processus des mots. On a divisé dans les expériences 3 et 4 des mots morphèmes soit avant soit après la liaison syllabique (ex: rePEL, rEPEL, ou repEL). Le stimulus primaire a été pseudo-morphème dans le sens où les syllabes initiales pouvaient apparaître comme un morphème dans d'autres mots (ex: repel). La seconde syllabe n'était ni morphème ni pseudo-morphème. En utilisant les mêmes AIS que dans les expériences 3 et 4, on a trouvé que les syllabes intactes facilitaient la reconnaissance du mot quand la AIS était courte, mais pas quand elle était longue. Pour autant, la syllabe remplie un rôle dans l'étape initiale de la reconnaissance des mots. On devra encore déterminer dans ce paradigme si les morphèmes qui ne sont pas des syllabes facilitent la reconnaissance ou non.

La sílaba y el morfema se conocen como variables lingüísticas importantes, pero ¿se encuentra esa información involucrada en las etapas iniciales del reconocimiento de palabras? La información sílaba-morfema se manipuló en la etapa temprana de nombramiento de palabras mediante el paradigma de presentación rápida del estímulo primario. Las letras en el estímulo primario se imprimieron con una mezcla de mayúsculas y minúsculas. El cambio de letra

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minúscula a mayúscula ocurría ya sea, en una liga sílaba-morfema, antes de la liga, o después de ésta (Ej., reTAKE, rETAKE, o retAKE), creando un par intacto o uno fracturado. El estímulo meta se presentaba siempre en minúsculas (Ej., retake). Los resultados de los experimentos 1 y 2 revelaron que la información intacta de la sílaba y el morfema facilitaba el nombramiento de palabras cuando la Asincronía del Inicio del Estímulo (AIE) era corta, pero no cuando era larga. Esto sugiere que el uso de tal información es automático. Un segundo grupo de experimentos intentó determinar si la información de la sílaba sola podría facilitar el procesamiento de las palabras. En los experimentos 3 y 4, palabras monomorfémicas se dividieron ya sea antes o después de la liga silábica (Ej., rePEL, rEPEL, o repEL). El estímulo primario fue pseudomorfémico en el sentido de que las sílabas iniciales podían aparecer como un morfema en otras palabras (Ej. restate), pero no eran morfémicas en las palabras blanco (Ej., repel). La segunda sílaba no era ni morfémica ni pseudomorfémica. Empleando la misma AIE que en los experimentos 1 y 2, se encontró que las sílabas intactas facilitaban el reconocimiento de la palabra cuando la AIE era corta, pero no cuando era larga. Por lo tanto, la sílaba desempeña un rol en una etapa inicial del reconocimiento de las palabras. Habrá todavía que determinar, en este paradigma, si los morfemas que no sean sílabas facilitan el reconocimiento o no.

The purpose of this study was to investigate whether two prominent linguistic units, syllable and morpheme, affect the cognitive process in printed word recognition. Evidence of the activation of syllabic or morphemic cognitive representations in an early stage of printed word recognition would indicate that the process is distinct from other types of visual processing such as object recognition.

There is some evidence from previous studies that the involvement of morphemes and syllables in word recognition is in the early stages of word recognition. Some experiments have used brief morphological priming (i.e., fast time scale priming) with a short Stimulus Onset Asynchrony (SOA) between the prime and the target word. These consistently show early activation of morphological representations (Deutsch, Frost, & Forster, 1998; Drews & Zwitserlood, 1995; Feldman, 2000; Frost, Forster, & Deutsch, 1997). These studies found effects of shared morphemes between prime and target over and above the effects of shared orthography (i.e., the orthographic control) or shared meaning between prime and target (i.e., meaning control). For example, Frost et al. (1997), using a 50 ms SOA, showed that a prime with the same root morpheme as the target facilitated processing of the target but a prime with merely similar meaning to the target did not. With regard to syllables, many studies show strong syllable effects in various kinds of lexical tasks (Butler & Hains, 1979; Klapp, Anderson, & Berrian, 1973; Prinzmetal, Treiman, & Rho, 1986; Spoehr & Smith, 1973). Prinzmetal et al. used distinctly coloured letters in a briefly presented word to identify the unit of perceptual analysis in word recognition. For example, for the target word *train*, the first, third, and fifth letters might be printed in red and the second and fourth in blue. The perceptual grouping of the similarly coloured letters would sometimes produce the illusion that the word presented was *TAN* (the letters that were in red). This kind of illusory conjunction between letters of a similar colour occurred more frequently within a syllable than between syllables. In other words, it was easier to form an incorrect perceptual combination of letters within syllables than between syllables. This suggests that there was a barrier to combining letters from different syllables—that a natural cohesiveness to the syllable unit exists that may play a role in printed word recognition. In another example, Spoehr and Smith (1973) argued that the syllabic unit is the basic unit in the early stage of word recognition. In tachistoscopic letter detection, their results showed that one-syllable words were recognized faster than two-syllable words, suggesting the influence of the number of syllables in an early stage of word processing.

The methodology we use to investigate the role of linguistic units in word recognition is to divide words by mixing the case (e.g., reTAKE). Several studies on mixed-case effects in word processing showed that case mixing leads to a disruption of trans-letter features, or to inappropriate letter grouping (Besner & Johnston, 1989; Mayall, Humphreys, & Olson, 1997; Mewhort & Johns, 1988; Paap, Newsome, & Noel, 1984). For example, T, A, and N in the word TrAiN would be grouped together because they are all upper case, leading to slower recognition of the whole word. By this logic, if the process of recognition depends on syllabic or morphemic representations, it would be faster and easier to process a word that is, using mixed case, divided at the boundary of the representations (e.g., reTAKE) than one divided by one letter before or after the boundary (i.e., rETAKE or retAKE).

Experiments in this study used a word of mixed case as a prime and its corresponding target word in normal case, e.g., reTAKE (prime) → retake (target). The SOA of the prime-target relationship was also investigated. An appropriately divided prime (reTAKE) may facilitate recognition of the target (retake) only at short SOA, only at long SOA, at both lengths, or at neither length. If the linguistic variables play an early role in recognition, as the studies we cited suggest, then effects should be found at short SOA but not at long SOA.

EXPERIMENT 1

As the first step in investigating whether syllables and morphemes affect word recognition, multi-morphemic words were used for a naming task in which participants spoke aloud a target printed in normal case. The target was preceded by a mixed-case prime. In Experiment 1, every stimulus word's syllables coincided with its morphemes (as in the word *retake*, for which each of the word's two syllables is also a morpheme). The mixed-case prime had three "related" conditions, in which the prime was an identity prime, i.e., it was the same word as the target (e.g., reTAKE → retake). In one of these related conditions, the prime was divided at the joint syllable-morpheme boundary (e.g., reTAKE). In the second and third conditions, the prime was divided at a point either one letter before or after the syllable-morpheme boundary (rETAKE and retAKE). Also, in order to assess the effect due to relatedness, a word prime unrelated to the target was used as the baseline for each condition (i.e., coSINE → retake, controlling for reTAKE → retake; cOSINE → retake for rETAKE → retake; cosINE → retake for retAKE → retake). Thus, there were six conditions, formed by the factorial combination of relatedness and boundary division. If syllable-morpheme information is instrumental in the process of identifying and naming a printed word, we should expect an interaction; division on the syllable-morpheme boundary should be facilitative but only for related primes.

Method

Subjects. Forty-two students enrolled in the Introductory Psychology class at the University of Texas at Austin participated in the experiment. The choice of subjects was assumed to represent a sample of typical skilled readers.

Materials. Twenty-four multi-morphemic words were selected to construct the main stimuli. They were 4–6-letter words with an average frequency of 248±57.96 according to the CELEX database (Baayen, Piepenbrock, & Van Rijn, 1993). These stimuli were used as targets. The experimental conditions were differentiated by the kinds of primes. The six stimulus lists all had the same targets but different types of primes: lists 1–3 had identity primes; a prime in list 1 consisted of a mixed-case word where the transition from lower to upper case (left to right) occurred one letter before the syllable-morpheme boundary (e.g., rETAKE → retake); a prime in list 2 consisted of a mixed-case word with a transition exactly at the boundary (e.g., reTAKE → retake); in list 3, a prime consisted of mixed-case word that divided at one letter after the boundary (e.g., retAKE → retake); list 4–6 were created with unrelated word prime as the baselines for lists 1–3; the prime condition in list 4 was the baseline for list 1 (e.g., cOSINE → retake), list 5 was the baseline for list 2 (e.g., coSINE → retake); list 6 was the baseline for list 3 (e.g., cosINE → retake). Constraints on the unrelated prime was that (1) there be no more than one letter overlapping with the target in the same position, and (2) the primes must be monomorphemic words. An additional 16 prime-target pairs were used as the practice trials. The stimuli for Experiment 1 are listed in Appendix A.

Design and procedures. There were two relatedness and three mixed-case types of primes, varied factorially, defining lists 1–6 (rETAKE, reTAKE, retAKE, cOSINE, coSINE, cosINE). These six lists were counterbalanced across participants in order to avoid a repeated target exposure to a subject. Participants were randomly assigned to the six different lists. Each subject saw a total of 24 stimulus pairs. During the experimental session, stimuli were presented to each subject in a different random order. The main experiment was preceded by 16 practice stimulus pairs. Participants faced a computer monitor from a viewing distance of about 60 cm.

Participants were instructed that two stimuli would appear at the centre of computer screen one after the other, and that their task was to read aloud the target with accuracy and speed. A four-field priming paradigm with the sequence of mask-prime-mask-target was used. The stimuli were presented with DMASTER software (developed at Monash University and the University of Arizona by K. I. Forster and J. C. Forster). The refresh rate of the PENTIUM monitor was 78 Hz, making a refresh cycle (i.e., a "tick") equal to 12.9 ms.

Each trial consisted of a sequence of four visual events in the same location in the centre of the screen: (1) a row of five hash marks for 490.2 ms; (2) a row of the mixed-case prime for 129 ms; (3) a row of ampersands for 154.8 ms; and (4) a lower-case word target for 1500 ms. The masks and words overlapped spatially with the pre- and post-prime masks, both of which contained the same number of symbols as the target. The duration of the prime (the prime-mask SOA) was set under 150 ms in order to reflect a pre-lexical stage of word processing (Neely, 1991). Reaction time (RT) was measured by a voice-activated switch.

Results

Response latencies of less than 100 ms and more than 1900 ms were discarded as outliers. These outliers were less than 0.4% of all responses (Ulrich & Miller, 1994). Responses with the naming errors were also discarded in the reaction time (RT) analysis. The mean latencies and their standard errors for each condition are summarized in Table 1.

TABLE 1
Naming latencies (ms), error rate (%), and standard error for the related and unrelated primes in Experiment 1

	Related primes			*Unrelated primes*		
Statistics	*rETAKE–retake*	*reTAKE–retake*	*retAKE retake*	*cOSINE–retake*	*coSINE–retake*	*cosINE retake*
Naming latency	431	411	427	453	456	454
SE	11.3	12.8	12.7	10.9	10.3	11.5
Error rate	0.9	0.7	0.8	0.7	0.6	0.9

The ANOVA was a 2 × 3 within-subject design, using Relatedness (related, unrelated) × Mixed-case type (case transition one letter before the boundary, at the boundary, one letter after the boundary). The analysis was conducted on reaction times of correct responses to targets, with subjects as the error term. The main effect of Relatedness was statistically significant, $F(1, 41) = 59.43$, $p < .0001$, but Mixed-case type was not, $F(1, 41) = 1.46$, $p > .10$. Importantly, the two-way interaction between Relatedness and Mixed-case type was statistically significant, $F(1, 41) = 3.18$, $p < .05$. Error analysis was not done because all error rates were below 1%. The pattern of two-way partial interactions between reTAKE–retake versus coSINE–retake (45 ms) and retAKE–retake versus cosINE–retake (27 ms) were similar to that between reTAKE–retake versus coSINE–retake (45 ms) and rETAKE–retake versus cOSINE–retake (22 ms). The post hoc analyses generally confirmed these patterns of results: Each partial two-way interaction was statistically significant or marginally significant, $F(1, 41) = 3.08$, $p < .06$ for the former, and $F(1, 41) = 5.51$, $p < .05$ for the latter.

Discussion

Words with mixed case have been used as a way to investigate whether word recognition is based on word-shape, i.e., holistic or global processing (e.g., Allen & Emerson, 1991; Allen, Wallace, & Weber, 1995; Coltheart & Freeman, 1974; Haber, Haber, & Furlin, 1983), or letter-based analytic processing (e.g., Besner & Johnston, 1989; Mayall et al. 1997; Mewhort & Johns, 1988; Paap et al., 1984). Studies supporting the holistic view showed that destroying the shape of a word slowed processing because case mixing affects the word-level code in the word recognition system. Further, it affects words more than nonwords, and high-frequency words more than low-frequency words. In contrast, studies supporting the analytic view showed that case mixing led to masking of lower-case letters by neighbouring upper-case letters, disruption of trans-letter features, or inappropriate letter grouping (e.g., T and A in the word ToAd may be grouped together). To use the term introduced by Katz, Lee, and Pugh (2000) and by Ziegler, Perry, Jacobs, and Braun (2001), word processing may proceed at either a small or large grain-size, with holistic processing involving large groups of letters (perhaps whole words) and small grain-size involving single letters or small letter clusters. Although the current study is not directly related with this debate, it suggests that the mixed-case priming task may well be useful when applied to the study of processing grain-size. In sum, a mixed-case prime that preserved the syllable-morpheme boundary facilitated naming of the target better than a mixed-case prime that broke the boundary. This suggests that linguistic variables have an effect in an early stage of word recognition and that the manipulation of mixed case can reveal these effects.

EXPERIMENT 2

Experiment 1 was carried out at a prime-mask SOA of 129 ms, too short a masked exposure to allow conscious processing of the prime. In Experiment 2, the prime-mask SOA was lengthened sufficiently (and therefore, the prime-target SOA as well) so that the subject would be aware of the prime. We expected this to eliminate the advantage of the intact syllable-morpheme boundary over the broken boundary conditions because we hypothesized that the effect of the linguistic variables we studied have their effect early in the word identification process. Although syllabic and morphemic effects may occur later in the process as well, their effects, if any, will be diluted by the many other factors playing roles, including semantic factors both general (e.g., word imageability) and idiosyncratic. Lukatela and Turvey (1994) have presented evidence that the effects of phonology, at least, will diminish when the SOA of the prime and the target is lengthened. This is because lengthened SOA provides room for other confounding variables to be involved in, obscuring the early automatic variable. In Experiment 2, we increased the SOA between the prime and its mask to 250 ms, well within the range of conscious processing (Neely, 1991).

Method

Subjects. Forty-two students, enrolled in the Introductory Psychology class at the University of Texas at Austin, participated in the experiment. This choice of subjects is assumed to represent the sample of the typical skilled reader.

Materials, design, and procedures. These were the same as in Experiment 1 except that the duration of the prime was longer. Thus, the mixed prime was presented for 258 ms, twice as long as the SOA of Experiment 1, and the mask that preceded the target was presented for 283.8 ms.

Results

Response latencies less than 100 ms and more than 2000 ms were discarded as outliers, and were less than 0.5% of all responses (Ulrich & Miller, 1994). Naming error responses were also discarded in the reaction time (RT) analysis. The mean latencies and their standard errors for each condition are summarized in Table 2. The ANOVA was a 2 × 3 (Relatedness × Mixed-case type), conducted on the correct reaction times to the targets with subjects as the error term. The main effect of Relatedness was statistically significant, $F(1, 41) = 15.47$, $p < .001$, but Mixed-case type was not, $F(1, 41) = 1.87$, $p > .10$. Importantly, the two-way interaction between Relatedness and Mixed-case type was not statistically significant, $F(1, 41) = 1.94$, $p > .10$. The pattern of performance, however, was similar to Experiment 1 in that the prime that maintained an intact boundary (i.e., reTAKE) facilitated naming speed. However, with the longer SOA of

TABLE 2
Naming latencies (ms), error rate (%), and standard error for the related and unrelated primes in Experiment 2

	Related primes			*Unrelated primes*		
Statistics	*rETAKE–retake*	*reTAKE–retake*	*retAKE–retake*	*cOSINE–retake*	*coSINE–retake*	*cosINE–retake*
Naming latency	314	290	315	351	357	359
SE	17.2	14.1	17.0	13.3	14.7	13.5
Error rate	0.5	0.3	0.4	0.6	0.5	0.6

Experiment 2, even the broken boundary primes (rETAKE and retAKE) had some facilitatory effect. The pattern of two-way partial interaction between reTAKE–retake versus coSINE–retake (67 ms) and retAKE–retake versus cosINE–retake (44 ms) were similar to that between reTAKE–retake versus coSINE–retake (67 ms) and rETAKE–retake versus cOSINE–retake (37 ms). However, the partial two-way interaction of the former was not statistically significant, $F(1, 41) = 2.01$, $p > .10$, although that of the latter was, $F(1, 41) = 4.39$, $p < .05$.

Discussion

The two-way interaction between Relatedness and Mixed-case type was not statistically significant at long SOA. The priming effect of an intact boundary item (i.e., reTAKE) was still substantial but the effects of a mixed-case prime that broke the syllable-morpheme boundary were also facilitative, although to a lesser degree. This suggests that the unique effect of an intact boundary prime is in the early phase of the identification process, as demonstrated by the short SOA manipulation in Experiment 1.

EXPERIMENT 3

Using multi-morphemic words, Experiments 1 and 2 showed that the linguistic variables of syllable and morpheme might play a role in an early stage of word recognition. Experiments 3 and 4 were designed in order to shed some light on which of the two linguistic variables, syllable or morpheme, is responsible for the superior facilitation of an intact boundary mixed-case prime.

English has words that look multi-morphemic but are not, in fact, composed of those morphemes. For example, the "re" in the word "repel" is not the common morpheme that a reader activates as "re" in "retake." Thus, when words like this (called pseudomorphemic words) are divided by an intact mixed-case transition as in rePEL, only the linguistic boundary of the syllables is marked, not any morpheme. The comparison of the effects of mixed-case primes, such as rEPEL, rePEL, repEL, with their appropriate controls, may provide information on whether the syllable is responsible for the better priming produced by a mixed-case item with an intact boundary. If there is better priming by mixed-case primes that delineate two intact syllables, one on either side of the case transition boundary, but not two intact morphemes, it would indicate clearly that syllable representations are involved at an early stage of word processing. With regard to morphemes, the experiment is inconclusive; morphemes may also be involved in addition to syllables but this experiment cannot address that question. On the other hand, if there were to be no benefit from a prime with an intact syllable boundary this would strongly suggest that the effects that we observed previously were due to morphemic, not syllabic, information—unless, of course, there is a synergistic facilitative effect caused by coincident syllable and morpheme representations.

Experiment 3 used the same short duration of SOA as in Experiment 1.

Method

Materials. Twenty-four pseudomorphemic words were selected to construct the main stimuli. They were 4–6-letter words and the frequency was 376 ± 58.09 according to the CELEX database (Baayen et al., 1993). These stimuli were used as the targets. The experimental conditions were differentiated by the types of primes. Six stimulus lists were created with different types of the primes and the same targets: lists 1–3 were created in order to investigate the effect of the syllabic effects by making lower-case to upper-case transitions in a different position of the word prime; the primes of list 1 consisted of mixed-case words with the case transition one letter before the boundary of the syllable (e.g., rEPEL → repel); the primes of list 2 consisted of mixed-case words in which the syllables were intact (e.g., rePEL → repel); the primes of list 3 were mixed-case words in which the case transition was one letter after the syllabic boundary (e.g., repEL → repel); lists 4–6 were created with unrelated word primes to be the baselines for list 1–3, in the same manner as for Experiments 1 and 2. An additional 15 prime-target pairs were used as practice trials. The stimuli for Experiment 3 are listed in Appendix A.

Design and procedures. There were six types of prime defined by lists 1–6 (rEPEL, rePEL, repEL, dOMAIN, doMAIN, domAIN). Design and procedures were the same as in Experiment 1.

Results

Response latencies less than 100 ms and more than 1800 ms were discarded as outliers, and were less than

0.5% of all responses (Ulrich & Miller, 1994). Naming error responses were also discarded in the reaction time (RT) analysis. The mean latencies and their standard errors for each condition are summarized in Table 3. The ANOVA was a 2 × 3 (Relatedness × Mixed-case type) conducted on the correct reaction times to targets with subjects as the error term. Main effects of Relatedness and Mixed-case type were both statistically significant, $F(1, 41) = 37.32$, $p < .001$ for Relatedness, and $F(1, 41) = 4.18$, $p < .05$ for Mixed-case type. Importantly, the two-way interaction between Relatedness and Mixed-case type was statistically significant, $F(1, 41) = 3.28$, $p < .05$. The pattern of two-way partial interactions between rePEL–repel versus doMAIN–repel (56 ms) and repEL–repel versus domAIN–repel (35 ms) were similar to results of previous experiments, as was the contrast between rePEL–repel versus doMAIN–repel (56 ms) and rEPEL–repel versus dOMAIN–repel (21 ms). The partial two-way interactions of the former was not statistically significant, $F(1, 41) = 2.36$, $p > .10$, but those of the latter were, $F(1, 41) = 8.22$, $p < .01$.

Discussion

The effects of a mixed-case prime that maintained an intact syllable boundary produced more facilitation against its baseline than any other condition, eliciting a statistically significant two-way interaction. However, a follow-up analysis showed that the difference in facilitation was mainly due to the difference between the intact syllable prime and the broken syllable boundary in which the transition came before the syllable boundary (rePEL versus rEPEL). The similarity between rePEL and repEL can be explained, at least in part, as due to the ambiguity of spoken syllable boundaries in English (in contrast to many other languages). In English, a single consonant between vowels may "share" itself with both, making, in effect, a geminate of the consonant. Thus, for example, repEL may become, when spoken, "rep" + "pel"; nearly all English speakers will find that pronunciation quite acceptable as an utterance of the printed word REPEL.

Syllabic effects have not always demonstrated their effects in previous studies that used one-word (i.e., non-priming) presentation as compared to the present priming study (e.g., Forster & Chambers, 1973; Frederiksen & Kroll, 1976). Thus, it seems like that the manifestation of syllabic effects may be restricted according to the experimental manipulation. Booth and Perfetti (2002) make a similar point when they suggest that syllable effects seem to be observed more easily in naming paradigms. We suggest that the paradigm/task used needs to focus on the early stage of word processing. However, we have no strong argument as to why the naming paradigm should be the best candidate for studying early processing. One piece of evidence in its favour is that it is well known that naming reaction times are faster than, say, response times in lexical decision, a task that requires a decision process.

EXPERIMENT 4

Experiment 3 suggested that syllable representations arise in an early stage of word naming. In this experiment, the effect of lengthening the SOA of the prime and the target is observed in order to determine if the effect of syllable information persists into later stages of the word naming process.

Method

Subjects. Forty-two students, enrolled at the Introductory Psychology class at the University of Texas at Austin, participated in the experiment.

Materials, design, and procedures. These were the same as in Experiment 3, except that the duration of the prime was longer; the same long duration as in Experiment 2, at 258 ms for the prime-mask SOA.

Results

Response latencies less than 100 ms and more than 1700 ms were discarded as outliers, and were less than 0.5% of all responses (Ulrich & Miller, 1994). Naming error responses were also discarded in the reaction time (RT) analysis. The mean latencies and their standard errors for each condition are summarized in Table 4. The ANOVA was a 2 × 3 (Relatedness × Mixed-case) conducted on the correct reaction times to the targets with subjects as the error term. A main effect of Relatedness was statistically significant, $F(1, 41) = 96.04$, $p < .0001$, but a main effect of Mixed-case type was not, $F < 1$. Importantly, the two-way interaction between Relatedness and Mixed-case type was not statistically significant, $F < 1$. The pattern of performance was not similar to that of Experiment 3. The pattern of two-way partial

TABLE 3
Naming latencies (ms), error rate (%), and standard error for the related and unrelated primes in Experiment 3

	Related primes			*Unrelated primes*		
Statistics	*rEPEL–repel*	*rePEL–repel*	*repEL–repel*	*dOMAIN–repel*	*doMAIN–repel*	*domAIN–repel*
Naming latency	471	436	465	492	493	500
SE	23.3	22.6	23.1	25.1	23.2	20.7
Error rate	0.6	0.8	0.9	0.7	0.6	0.8

TABLE 4
Naming latencies (ms), error rate (%), and standard error for the related and unrelated primes in Experiment 4

	Related primes			*Unrelated primes*		
Statistics	*rEPEL–repel*	*rePEL–repel*	*repEL–repel*	*dOMAIN–repel*	*doMAIN–repel*	*domAIN–repel*
Naming latency	325	325	327	363	367	373
SE	20.5	17.7	19.2	16.6	19.3	20.6
Error rate	0.9	0.5	0.6	0.8	0.7	0.7

interaction between rePEL–repel versus doMAIN–repel (42 ms) and repEL–repel versus domAIN–repel (46 ms) were similar to that between rePEL–repel versus doMAIN–repel (42 ms) and rEPEL–repel versus dOMAIN–repel (38 ms). Neither partial two-way interactions were statistically significant, *F*s < 1.

Discussion

In sum, there was no superiority to items with an intact syllable boundary; all types of boundaries, intact and broken, produced similar amounts of naming facilitation for the target. Syllabic effects disappeared when the prime-target SOA was long, indicating the much lesser role of the syllable in a later stage of word recognition.

GENERAL DISCUSSION

How early in the process of recognizing a printed word can we find evidence of phonologic (specifically, syllabic) representations? How early is there evidence of morphologic representation? These questions were investigated by preceding target stimuli with primes that were mixed-case words partitioned either appropriately or inappropriately by the relevant representation. Experiment 1 used a short interval between prime and target and showed that a mixed-case prime whose case transition was at either a syllabic or morphological boundary (i.e., reTAKE) facilitated naming of the target (e.g., retake), compared with a mixed-case prime whose case transition broke the syllable-morpheme boundary (e.g., rETAKE or retAKE). This suggested that syllabic or morphological information plays a role in early stages of word recognition. Experiment 3 showed that a mixed-case prime that preserved the syllable boundary (without respect to the morphology) also facilitated target performance. This suggested that facilitation of target naming in Experiment 1, in which the syllable-morpheme representations were confounded, might be attributable, at least, to the syllable information. Experiments 2 and 4, employing a longer SOA than Experiments 1 and 3, showed a smaller and weaker effect of mixed-case priming, suggesting that the early effects of syllable priming either dissipated quickly in the word identification process or were conflated with other effects later in that process.

A significant limitation of this study is, of course, that there was no experiment in which the mixed-case prime was partitioned at a morphological (but not syllabic) boundary (e.g., FASTer → faster, for suffix). This would have provided an opportunity to compare the relative role of syllable and morpheme in word processing. The realization of this condition, however, has a collateral limitation in comparing it with the role of the syllable. This is because most of the possible mixed-case primes that are partitioned only at a morphological boundary (but not at a syllable boundary) are words with suffixes, not prefixes, as the word in Experiment 1–4. Thus, the direct comparison itself would be confounded. In addition, the ambiguity of English syllable boundaries becomes more critical for these stimuli.

The facilitation of the target by a syllabic prime in Experiment 3 and no facilitation in Experiment 4 are results that are compatible with previous studies showing the strong role of phonology in early word-processing stages (e.g., Lukatela, Eaton, Lee, & Turvey, 2001; Lukatela & Turvey, 1994, 2000; Luo, 1996). Although the syllable is a larger phonological unit than the phoneme, which was addressed in these studies, the idea of syllable representations being instrumental in the word identification process receives support from the same theoretical approach. The phonological recoding hypothesis of Van Orden, Pennington, and Stone (1990) argues that the resolution for the network of orthography and phonology is much faster than the one for the network of orthography and semantics because of the much higher self-consistency between orthography and phonology. If we add an assumption that the network of orthography and phonology is evolving to determine syllabic units following the identification of the phoneme units, the early role of syllable information extracted from the orthographic information can be understood.

This successful use of mixed-case priming suggests that this paradigm may be useful for studying other aspects of printed word recognition. As the manipulation of the prime in current experiment was proven to be effective in differentiating the processing of the target, this type of manipulation can be used as a new method to investigate the early stages of word processing. As compared to a single-word presentation (such as a standard naming task) the manipulation of primes in the fast time scale can reveal how the early stages of word recognition may involve linguistic representations.

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APPENDIX A

Stimuli used in Experiments 1–2		*Stimuli used in Experiments 3–4*	
Related	*Unrelated*	*Related*	*Unrelated*
endow	macro	entire	listen
entrap	banzai	indeed	office
expel	crave	midget	octave
inject	mingle	enigma	melon
induct	office	pretty	expect
imbue	prong	preach	soccer
midway	opaque	regret	hurtle
misuse	camden	result	modern
outrun	poodle	retch	saber
premix	nikkei	repel	domain
prefab	candor	reign	apron
retake	cosine	consent	mercury
retell	doodle	comedy	barrel
reuse	flout	dismal	coward
retest	mohawk	engine	county
recap	mikey	infant	chapel
rearm	elope	reckon	hazard
renew	spice	uncle	beach
redo	hope	premium	othello
untrue	sermon	interim	monarch
update	verify	remedy	darwin
unless	figure	indigo	harrow
unhappy	classic	prosaic	wrinkle
embark	hamper	benign	arabia