Fluency Can Bias Masked Priming of Binary Judgments: Evidence From an All-Nonword Task

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Using a novel all-nonword task (“Does the target have more vowels than consonants?”), we provide new evidence that processing fluency can bias masked priming of binary judgments. Two experiments revealed masked repetition priming for “yes” nonwords (e.g., NUISO) but not for “no” nonwords (e.g., RULON). We take this pattern as evidence that the greater ease of target processing induced by repetition primes was attributed to the target being a member of the response category associated with shorter reaction times, namely the “yes” response category. This pattern of nonword priming effects reinforces Bodner and Masson’s (1997) key claims: (1) a fluency-attrition process can influence masked priming, and (2) therefore, the masked-priming paradigm does not isolate lexical processes.

Keywords: masked priming; nonword priming; fluency bias; lexical decision

Responses to targets can be facilitated by brief masked primes of which participants are unaware. Consistent with a lexical basis for priming (e.g., Forster & Davis, 1984), masked repetition (vs. unrelated) primes typically facilitate lexical decisions for words but not for nonwords (e.g., Forster, 1998). Building on earlier work, Bodner and Masson (1997) argued that masked priming for nonwords might be obscured in the lexical-decision task by a fluency bias, whereby an increase in processing speed on repetition trials might be attributed to the target being a word, creating a bias that works against making correct responses to nonwords (e.g., Balota & Chumbley, 1984; Feustel, Shiffrin, & Salasoo, 1983).

Processing fluency has been shown to affect a variety of binary judgments (e.g., Jacoby, 1983; Jacoby & Dallas, 1981; Whittlesea; 1993; Whittlesea, Jacoby, & Girard, 1990). When the processing of a stimulus is experienced as fluent, observers seek to attribute that fluency to a source. In a recognition task, fluency is often attributed to prior study. For example, masked repetition priming of targets elevates recognition claims (Jacoby & Whitehouse, 1989; Rajaram, 1993). Fluency can be attributed to other task-salient sources too, ranging from visual clarity (Jacoby, Allan, Collins, & Larwill, 1988) to fame (Jacoby, Woloshyn, & Kelley, 1989).

Bodner and Masson (1997) obtained robust priming for nonwords in the lexical-decision task by presenting targets in mIxEd-cAsE format. They took nonword priming as support for a memory-based account of priming originally proposed by Whittlesea and Jacoby (1990). Specifically, on their memory-recruitment account (see Bodner & Masson, 2014, for a review), the processing applied to masked primes is encoded into a new memory trace that can be retrieved to assist with processing of the target. The overlap in prime and target processing on repetition-prime trials should facilitate responses to both words and nonwords unless a fluency bias works against nonword priming. Bodner and Masson argued that presenting targets in mixed-case format decreases processing fluency while increasing reliance on the processing applied to the prime (see Whittlesea & Jacoby, 1990). The conjunction of these two outcomes was argued to reveal nonword priming.

This explanation for nonword priming—and the general claim that fluency can bias masked priming—has since been challenged (see Kinoshita & Norris, 2011). For example, Davis, Kim, and Forster (2008) suggested that mixed-case format might lead targets to be processed on a letter-by-letter basis by opening letter entries which would promote priming for words and nonwords alike. Consistent with this possibility, Davis et al. did not find nonword priming in a backward lexical-decision task in which uppercase targets were used, but had to be processed from right to left (e.g., DAOR for word target ROAD).

In Norris and Kinoshita’s (2008) Bayesian Reader account, masked priming reflects the conflation of brief, masked primes with their visible targets. This conflation is combined with information about a target’s likelihood based on prior experiences or “priors” to optimize responding in a given task. Norris
and Kinoshita tested this account using a novel same-different judgment paradigm. Before each masked priming trial a referent item was shown in plain view. Participants had to decide whether the target matched the referent (same trials) or not (different trials). Priming occurred for words and nonwords on same trials but neither showed priming on different trials. Importantly, then, the Bayesian Reader account does not predict nonword priming in the standard masked-priming paradigm where a nonword prior is not established via the presentation of a referent nonword at the start of the trial.

Perea, Gomez, and Fraga (2010) examined a second reason why masked priming might be underestimated for nonwords in the lexical-decision task: Nonwords are always mapped to the “no” (vs. “yes”) response. They reasoned that nonword priming might be larger in a nonword-based go/no-go task (i.e., respond “yes” to nonwords; withhold response to words). Contrary to the sublexical letter-level account described above, using uppercase targets they obtained small but significant nonword priming effects that were similar in size in this novel task and in a standard lexical-decision task (i.e., respond “no” to nonwords; respond “yes” to words). Perea et al. concluded that response mappings in the lexical-decision task do not work against nonword priming. However, they assessed priming for “yes” versus “no” responses to nonwords using different tasks. Moreover, fluency experienced on a lexical-decision trial might typically be attributed to the target being the more efficiently processed target type (i.e., a word, rather than a nonword). If so, a fluency bias against nonword priming will be present whenever words are one of the two target types, which is as true of the nonword-based go/no-go task as the standard lexical-decision task.

Experiment 1

To provide a definitive test of a fluency bias, we created a novel binary-judgment task that used only nonword stimuli. Participants decided whether each 5-letter target contained more vowels than consonants. Nonwords with more vowels (i.e., “yes” nonwords) were expected to be more fluently processed than nonwords with fewer vowels (i.e., “no” nonwords), as evidenced by shorter reaction times (RTs). If fluency from repetition priming is attributed to the more fluent response category, then a fluency bias should yield priming for “yes” nonwords but not for “no” nonwords. This bias was not expected to produce negative repetition priming for “no” nonwords because the overlap in prime and target processing should work to facilitate target classification, at least according to the memory-recruitment account (Bodner & Masson, 1997). On the lexical account, priming should be absent for both “yes” and “no” nonwords given that neither reside in a mental lexicon. On the Bayesian Reader account, nonword priming should again be absent because a nonword prior has not been established for the prime to update. Finally, on a sublexical account, our use of uppercase targets should not induce a letter-by-letter strategy, but if it does, then this account predicts equivalent priming for “yes” and “no” nonwords.

Method

Participants. University of Calgary undergraduates participated for course credit, 70 in a first experiment and 40 in a replication. The key findings did not differ across data sets so they were pooled.

Materials and design. The critical stimuli were 200 5-letter nonword strings (Appendix A). The 100 “yes” nonwords contained 3-4 vowels and the 100 “no” nonwords contained 1-2 vowels. Unrelated primes shared the same number of vowels as their targets, thus primes were always predictive of the correct target response. Half of the targets of each type were assigned repetition primes and half unrelated primes; this assignment was counterbalanced across participants. Additional practice targets (10 per type) with unrelated primes were selected using these criteria.

Procedure. Stimuli were presented in black 12-point courier font on a white background on a Macintosh computer using software that synchronized with the monitor’s 16.7-Hz refresh cycle. Participants were not informed about the primes. Each trial consisted of a 495-ms mask (a row of uppercase Xs), followed by a 45-ms lowercase prime, then an uppercase target that remained visible until a response. Each stimulus appeared at the center of the monitor. Participants were asked to read each target silently and then indicate as quickly and accurately as possible whether it had more vowels than consonants by pressing the “/” or “z” key, which were mapped to “yes” or “no” responses in a counterbalanced fashion. Feedback appeared for 1 s if no response occurred within 1.5 s (“Too Slow”) or if an error occurred (“Incorrect Response”). A 1-s intertrial interval then occurred. After 20 randomized practice trials and 200 randomized critical trials, participants were questioned to assess their subjective prime awareness.

Results and Discussion

Only 4 participants (3.6%) reported prime awareness. Following Bodner and Johnson (2009), trials with RTs below 300 ms (0.33%) or above 1,850 ms (0.90%) were omitted. The significance level was .05. Figure 1 plots the mean RTs on correct trials, and the error rates, for “yes” and “no” nonwords by prime.
type. Each dependent measure was analyzed using a 2 (priming: unrelated vs. repetition) x 2 (target type: yes vs. no) ANOVA.

In the RTs there was an overall priming effect, $F(1, 109) = 19.43$, $MSE = 1,099$, $p < .01$, that interacted with nonword type, $F(1, 109) = 6.34$, $MSE = 1,203$, $p < .05$. Responses were also much faster for “yes” than “no” nonwords overall (824 ms vs. 926 ms), $F(1, 109) = 261.71$, $MSE = 4,343$, $p < .01$, consistent with “yes” nonwords being the more fluent response category. Most importantly, and consistent with the fluency bias described by the memory-recruitment account, follow-up tests showed that priming was significant for “yes” nonwords (22 ms), $F(1, 109) = 26.56$, $MSE = 1,027$, $p < .01$, but not for “no” nonwords (6 ms), $F(1, 109) = 1.36$, $MSE = 1,276$, $p = .25$. The lexical, sublexical, and Bayesian Reader accounts do not predict this pattern. By analogy, this pattern suggests that masked repetition priming in the lexical-decision task likely also biases decisions toward the more fluent response option, namely “yes” (word) decisions, thus undermining nonword priming in this task. Consistent with this possibility, masked priming effects for words and nonwords are more similar when the target format (Bodner & Masson, 1997) or task (Masson & Isaak, 1999) de-emphasize a reliance on fluency.

The error rate was similar for “yes” and “no” nonwords, $F < 1$, $p = .53$. Unexpectedly, however, participants made more errors on repetition (vs. unrelated) trials (18.6% vs. 17.1%), $F(1, 109) = 6.39$, $MSE = 37.5$, $p < .01$. Critically, however, this negative priming effect did not interact with target type, $F < 1$, $p = .75$. Nonetheless, repetition priming yielded faster responses but more errors, indicating a speed-accuracy trade-off for “yes” nonwords. Experiment 2 was conducted in an effort to replicate the priming pattern in RTs without the complication of a speed-accuracy trade-off.

Figure 1. Experiment 1: Mean RTs and error rates as a function of prime type for each type of nonword target. Error bars for RTs and error rates are 95% within-subjects confidence intervals for comparing pairs of means across prime type. Error bars for priming effects are 95% confidence intervals for comparing priming effects against zero.
Experiment 2

A new set of nonwords was used in Experiment 2, both to establish generality and to provide better stimulus control than in Experiment 1. Here both “yes” and “no” nonwords were built from the same sets of letters and were matched for letter frequencies.

Method

We tested 30 additional participants from the same pool as in Experiment 1. New 5-letter “yes” and “no” nonword strings were constructed from 5 vowels (E, A, I, O, U) and the 5 most-common consonants (R, T, N, S, L). For each set, 10 practice and 100 critical targets/unrelated-prime pairs were generated as in Experiment 1 (see Appendix B). Prime assignment followed Experiment 1. The “yes” nonwords contained 3 vowels and the “no” nonwords contained 2 vowels; their mean letter frequencies were equated (35.2 vs. 35.2), and their forward bigram frequencies did not differ significantly (888 vs. 1001), $F(1, 198) = 1.22, MSE = 530,070, p = .27$, but the “yes” nonwords had more syllables (1.97 vs. 1.84), $F(1, 198) = 7.49, MSE = .11, p < .01$. The procedure matched Experiment 1 except the prime duration was 60 ms.

Results and Discussion

No participants reported prime awareness. Trials with RTs below 300 ms (0.53%) or above 1,850 ms (0.81%) were again omitted. Figure 2 provides the means, which were analyzed as in Experiment 1. Responses were again faster for “yes” than “no” nonwords (759 ms vs. 832 ms), $F(1, 29) = 61.98, MSE = 2,634, p < .01$, verifying that “yes” was the more fluent response option. The marginal priming effect, $F(1, 29) = 3.66, MSE = 1,143, p = .07$, was qualified by a significant interaction with target type, $F(1, 29) = 5.18, MSE = 875, p < .05$. Replicating Experiment 1, priming was significant for “yes” nonwords (24 ms), $F(1, 29) = 13.57, MSE = 642, p < .01$, but not for “no” nonwords (-1 ms), $F < 1, p = .96$. There were fewer errors for “yes” than “no” responses (12.7% vs. 17.4%), $F(1, 29) = 8.93, MSE = 72.2, p < .01$, and, importantly, the error rates on repetition and unrelated trials were similar (14.9% vs. 15.2%), $F < 1, p = .80$ (the interaction was $F < 1, p = .35$). Thus, the priming pattern in the RTs was the same whether a speed-accuracy trade-off was present (Experiment 1) or absent (Experiment 2).

General Discussion

A “wordless” vowel-judgment task revealed new evidence that a fluency bias can modulate masked repetition priming for nonwords (cf. Perea et al., 2010). We obtained nonword priming for the faster and hence more fluent “yes” targets (i.e., nonwords with more vowels than consonants), but not for the slower and hence less fluent “no” targets (i.e., nonwords with fewer vowels than consonants). Our finding that fluency can bias participants toward the more fluent response option raises the possibility that priming in the lexical-decision task may be underestimated for words (“yes” targets) and overestimated for nonwords (“no” targets)—in turn exaggerating evidence for a lexical account of priming (Forster & Davis, 1984).

Proponents of a lexical account sometimes attribute nonword priming to a sublexical letter-level process (e.g., Davis et al., 2008), but such a process should have yielded priming for both “yes” and “no” nonwords. The current pattern of nonword priming thus challenges a purely lexical or sublexical account of priming (Forster & Davis, 1984), but is consistent with the memory-recruitment account (Bodner & Masson, 1997), although the latter account has its shortcomings (see Bodner & Masson, 2014). Finally, although the Bayesian Reader account (e.g., Norris & Kinoshita, 2008) predicts masked nonword priming under some conditions, it does not predict it when a nonword referent is not presented prior to each masked priming trial.

If fluency simply biases yes responses, then reversing the task instructions might reverse the priming pattern for the two classes of targets. That is, a nonlexical-decision task might yield more priming for nonwords than words, and a consonant-judgment task might yield more priming for nonwords with more (vs. fewer) consonants than vowels. On the other hand, reversing the task instructions would not likely change which target type is more fluently processed (i.e., nonwords with more vs. fewer vowels). If fluency is attributed to the more fluent target type, as we have suggested, then the priming pattern is unlikely to reverse. Indeed, people have strong natural tendencies in their treatment of binary response options (e.g., Proctor & Cho, 2006). Informally we have also found that participants given “reversed” task instructions tend to “un-reverse them” to foreground the easier, better-known target type (i.e., words, vowels).

Our findings can be reconciled with the lexical, sublexical, or Bayesian Reader accounts of masked priming by acknowledging that processing fluency influences participants’ binary responses. For example, in the Bayesian Reader account, confusions of perceptual processing of masked repetition prime/target pairs could be processed more fluently than confusions of unrelated prime/target pairs. In other words, the occurrence of a fluency bias does not adjudicate between accounts of the processes that
generate priming or that guide the execution of binary responses. Instead, it reaffirms that cognitive operations generate experiences of processing fluency that may work to exaggerate some priming effects while masking others.

References


Critical Practice
Yes TARGETs and unrelated primes


Appendix A
Experiment 1 Stimuli

Yes TARGETs and unrelated primes

Practice: APOOD ineeq, AIRYP oysas, AFEAQ ohaoz, HEYYA bacoo, PERAI suloy, IPEAD aroog, AADIR oepav, CROEY squay, DEAZY coova, BOLOA tafei

Critical: EWERA inony, SAIRY pooba, TOUME hooley, ANIFE ohabo, SEERA foaby, SEERO vaimy, OUTHY ayrla, AXAME orifa, OTOUS aquid, FAUCE toiky, TOADE poila, CONUA goeoy, TOINE poeba, YARBY aeplo, BOODU kaife, TOMII nafa, PEATU ziipa, ULEER atoom, AANEK uulaz, IPOIF arood, ZAUXE moita, COGAA habi, ZIZEE wofay, AEDAL yonir, BEAZA soore, OABLE yomre, OUSEP aitoh, EKALY oro, RISAI sewey, AMOCY onixi, SAEI gloure, MATYA fwooe, QEAPE soudy, WAGOI qine, INEN ekeo, EAYRI aaido, AHEYS ofout, YANDI aitca, ARUET bioge, YOORE aetia, GRIO plouy, FOESY doena, EITCA yobwo, DOUBI paene, BLEEE spoo, SILYA haruy, AALON eecut, AREF ebuit, AUNKY oylvi, OERUF aiteq, OHILA edaru, BULYE hanto, UHEIV ozuu, ARUYA yoike, ARAPO edo, AGIYA osoue, HIEAT gyoov, HOOMY tie, TOVAA hazai, OLEEN emyot, OUSHY aarvy, CEEAN pyai, OOSQYE yerto, EAAUQI ainau, ATICE efqo, OESER yunim, EASHI oiss, MERAY titoo, OCKYA essue, AULKY iilla, AHALA orowo, YEVEW aisos, ARICY emona, PALIE korai, JOULA kaizo, TOROY palai, PEAGO taoda, OOLIQ eafem, JREYA pleio, AWEAM ocaib, ARFIE aggoy, SURAY wikee, AVOIQ eheab, ROYAR veoel, ARAUM usoip, UDIIT arto, AECAT oomiw, AILOM oekel, UWISU epey, AWUIZ ibeez, YEAQR ouyr, OLIK utuep, AREFE owa, ANOUT olaar, BUESY coome, ARAES ipood, POREE damay, ZAIVY foowa, OHOVE asate, KOWEY saic.

No TARGETs and unrelated primes

Practice: STRIE krloo, LORPE geroq, ILGUZ impyr, TRETI gli, DONVY fapi, QUEWP soak, ELEFNY wuck, CRPUE tchay, SOVET fazeq, ALIND oreft

Critical: AFLLE ackri, BROOP zlaid, FRAMY plora, GADAP soqud, WATIH rodaz, ZUILT poerd, HEVID woneh, KLEAP crail, WRABE prieq, PEAMS tair, DRENK treld, JENDO razpa, CUSAT migen, GOEWN quigg, PENOC nazer, ZORSMA pelmu, ORRTY affla, SALFU karne, CIMUB gata, CLORN plabr, XOUNT baifs, STEAN vlouz, KEARN vouf, VOWER sapat, FLACE vrah, SLORY ghae, SMIRE fregy, MIPOQ qung, BARZI hosh, PLAWE fripa, FRIEF prua, DOOSU maige, PRAIN dreas, HILUT rocar, SELIL zunas, SCREF elnem, PANDY tarfa, GLOUP sneb, ERRON artas, SMONE vlisa, WRONE flela, THAIM spoood, GOSTE yusta, VADKU rusco, WOOTH mirz,
Appendix B

Experiment 2 Stimuli

Yes TARGETs and unrelated primes
Practice: SAIRU loeta, NAITU seuri, ULSIE ertime,
NUAIR loies, AURIT oelun, OTELU irase,
NULIE taroi, SOUTE laino, LUEIT saoen,
RELOU notai
Critical: LOUSI reato, OILUS eorat, LOUNI tiesa,
OULIN ietas, LASOU tunie, SOULA netu,
NUISO loena, SINOU nelao, OUITL iears, LITOU rasie,
AULSI ectrui, LAUSI toeur, IRLOU onseae,
UROIL aseon, OURSI ielna, SOURI niela,
ALOUT usien, TOULA neisu, OINTU aeso,
TOUNI laose, AUINS coalt, USAIN oteal, AUIS
ioelt, SUITA roeli, OURNI easlu, RINOU sulae,
AIRLU outne, LAURI noetu, ANTOU orlie,
TANOU lorie, OUELS aium, SOULE nairu,
OURAN ietol, RANOU tolie, ROUTA leiso,
UTARO isole, LOUEN reiat, OELUN earit,
OUENS aiotl, SENOU tola, AIOLS eurit, SLOIA
trieue, LAUSE toine, SLEAU ntaio, SUNIE leroa,
UNIE erola, EUIITS oaur, SITUE luroa, ORUES
tuiot, SEROU tila, LIERU sauno, URILE onas,
NOUTE railee, OUNTE aircu, OTAIL ineuer,
TOILA niure, ANUSE eliro, EAUNS oeiit, OASTI
aurne, TOASIA naure, EAUST ouini, SEATU nouli,
AIROL otes, RAIOLO touse, TOURE saliu,
UTORE isalu, EURNI oaste, UNIRE ateso,
OINTA aulsie, TOINA lause, AUTEN oiral,
TAUEN roial, ANOIR oteul, OARNI uolet,
ORTAI iisue, TROYA sliue, LONIE surao, OLIEI
usuaro, EISON aulet, ONISE etula, ALISE onuta,
EILAS aunot, ELROI insau, LORIE nasui, EIOIR
aount, ROISE nauto, OATLE eursi, TOELA resiu,
TOEIN liaus, TOINE liua, AINES oual, ENAIS
atoul, SEATI loiru, TASIE riluo, ENIOR auel,
ERION aules, ARLEI isnou, OTEAN aruis,
TENAI salou, ORTAE unsoi

No TARGETs and unrelated primes
Practice: OARLS eistn, SBROI rutla, ALTOO ursli,
ERLUT antol, ROSIT lenar, SURTE nolsa, ASTIN
erlos, OARNS eilt, LAIRN touls, SARTO tenlu
Critical: SLUNI treso, LORUS tanil, TALUS liron,
RULON terse, ULNOR esrat, TRULO sneri,
LORUT rines, RULSA setno, SULAR netos,
SNURI trale, SURNI talre, LUNTA torle, ALNUT
etrol, STUNA iriso, SANUT losir, RONTU nalse,
UNTRIO elmsa, RALTU tosni, TRULA ntiso,
SRATU lnose, TAURS soeal, LUENS taolr,
SLUNE litora, EULST osirn, SUTEL niors, LORIS
tanul, ROLIS natul, ELURS otnil, LURSE tinlo,
LATOS renul, OALTS uernl, LASIN nurat,
LISAN nart, SUTEN nalir, NUTES ralin, NOLRI
ratse, RINLO tersa, LUREN tons, ULNIS otsin,
LORIT sanul, TRILO inorl, TALUS liron,
RULON tesar, ULNOR esrat, TRULO sneri,
STONIA truse, TOANS ruest, ANTIL oser,
TANLI lorse, NORTAL tins, RALON sinut,
LORAT silur, TARLO ruls, TRONI saielt, TROIN
slaet, RUTEN lissar, TRUNE silra, IRALT oners,
LARTI renso, RAITTS tioul, RATSNI tolun, ESNIL
urtas, LENIS sutar, SILET lorum, SITLEI lonru,
NARTI suln, RITAN lens, SERIAL rotun, SLEIRI
nottu, NESIO ransu, SOTEN niasr, LEATS roiln,
SELTI norli, LERNO rutsa, ORNEL atsr,
OLERT isult, TROLE nislu, ALSER ontul,
SLERA tmluo, IRSEN anil, SNIER ltain, ENTAL
orst, TELAN soth, ASTEN irlos, SNATE rsilo,
NETERI taul, TOREN slat, ARSEN olit,
SERAN tilor, TERLAI nostr, TREMEL nsout,
RENIT noals, TIREN lanos, SATER nisul, SETRA
nusli, NARTE lonsi, TRENIA snilo