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BRIEF REPORT

Priming of abstract letter representations may be universal: The case of Arabic

Manuel Carreiras · Manuel Perea · Reem Abu Mallouh

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Abstract Recent research on the Roman alphabet has demonstrated that the magnitudes of masked repetition priming are equivalent for letter pairs that have similar visual features across cases (e.g., c–C) and for letter pairs with dissimilar features (e.g., g–G). Here, we examined whether priming of abstract letter representations occurs in an orthographic system, Arabic, in which the letters show an intricate number of contextual forms. Arabic does not have a lowercase/uppercase distinction, but the letters exhibit different forms that depend on their position (initial, medial, final, or isolated) and their connectivity. Importantly, some letters look quite different across positions (e.g., ـعـ and ع, which correspond to the letter *'ayn*), whereas others look very similar (e.g., ـفـ and ف, which correspond to the letter *fā'*). We employed a masked priming same–different task, in which native speakers of Arabic decided whether a target letter was the same as or different from a reference letter presented in a different position (middle vs. isolated). The results showed masked repetition priming effects of the same magnitude for letter pairs with similar and with dissimilar visual features across letter positions. These data support the view that priming of abstract letter representations is a universal phenomenon.

Keywords Masked priming · Word recognition · Letters · Reading

M. Carreiras · R. A. Mallouh
Basque Center on Cognition, Brain, and Language,
Paseo Mikeletegi, 69,
20009 Donostia-San Sebastián, Spain

M. Carreiras (✉)
IKERBASQUE, Basque Foundation for Science,
Bilbao, Spain
e-mail: m.carreiras@bcbl.eu

M. Perea
ERI-Lectura, Universitat de València,
Valencia, Spain

Reading is one of the most complex and critical skills that humans have to master in our society. In alphabetic orthographies, reading involves the recognition of printed words. Words are not processed at a holistic level, but rather are processed via their constituent letters (Rayner, McConkie, & Zola, 1980; see also Pelli, Farell, & Moore, 2003; Perea & Rosa, 2002). The formation of letter representations at an abstract level may be critical for efficient processing of visual-word recognition and for learning to read. Thus, examining how readers process and have access to the abstract (shape-invariant) representations of letters in different orthographic systems is essential to unveiling the cognitive processes underlying normal reading.

Research using psychophysical techniques has revealed that letters are identified via their constituent features (e.g., Jacobs, Nazir, & Heller, 1989; Solomon & Pelli, 1994). Critically for the purposes of the present article, a number of studies have examined the roles of visual information versus abstract letter information during the early stages of letter identification using the masked priming paradigm (Forster & Davis, 1984). In this paradigm, prime stimuli are presented briefly enough to prevent the use of conscious predictive strategies, which often influence experiments with visible primes. In most of these experiments, primes and targets have varied either in terms of visual similarity (e.g., c–C vs. a–A) or in terms of name (i.e., abstract letter) identity (e.g., a–A vs. c–A), in either an alphabetic decision task (speeded classification of the target as a letter vs. non-letter) or a letter-naming task ("name the target letter").

Masked priming effects using the letter-naming task occur to similar degrees for visually similar lower- and uppercase versions of a given letter (e.g., c–C) and for visually dissimilar combinations (g–G) (Arguin & Bub, 1995; Bowers, Vigliocco, & Haan, 1998; Ziegler, Ferrand, Jacobs, Rey, & Grainger, 2000). Although this finding is consistent with the existence of early abstract representations for letters (Arguin & Bub, 1995), the letter-naming task may be overly sensitive to phonological–articulatory factors (Bowers, Vigliocco, & Haan, 1998; Grainger, Rey, & Dufau, 2008). In addition, studies using the alphabetic decision task with the masked priming paradigm have revealed greater masked priming effects across lower- and uppercase versions of the same letter when they are visually similar (c–C) than when they are visually dissimilar (a–A) (Bowers et al., 1998; Jacobs & Grainger, 1991; Ziegler et al., 2000). Nonetheless, the alphabetic decision task does not necessarily require unique letter identification. That is, a positive alphabetic decision response can be generated on the basis of global letter activity, defined as the summed activation across all letter representations, rather than on the basis of a specific abstract letter representation (Arguin & Bub, 1995; Kinoshita & Kaplan, 2008). Therefore, neither the naming task nor the alphabetic decision task allows us to make strong inferences about the core processes underlying abstract letter identification.

To examine in depth the nature of letter processing, it is important to use a task that does not involve either naming or alphabetic decision. One such task is the masked priming same–different matching task (see Kinoshita & Norris, 2009, for a review). This task is an adaptation of the Forster and Davis (1984) paradigm with a same–different task. In the typical setup, a probe stimulus is presented before the target for about 1,000 ms, and the participant has to decide whether the target is the same as or different from the probe. When the probe and target are the same (e.g., probe, *house*; target, *HOUSE*), response times to the target are faster when it is briefly preceded by a related prime (e.g., *house*) than when it is preceded by an unrelated prime (Norris & Kinoshita, 2008; Perea, Abu Mallouh, García-Orza, & Carreiras, 2011; Perea & Acha, 2009). Importantly, Kinoshita and Kaplan (2008) employed this task to investigate priming of abstract letter identities. Using probes and targets in different cases, they found masked repetition priming effects of the same magnitude for letters with similar visual features across cases (probe–prime–target: c–C–C faster than c–X–C) and for letters with dissimilar features across cases (a–A–A faster than a–B–A). These data support the view that "priming of abstract letter identities" takes place with the Roman alphabet.

To our knowledge, all previous published studies on visual versus nominal letter representations have been conducted with the Roman alphabet. Therefore, it is uncertain whether the effects obtained are specific to this alphabet or rather reflect a universal mechanism of letter processing. We believe that it is critical to investigate the effects of visual similarity versus name overlap in alphabets with very different characteristics. Arabic is the second most widely used alphabet in the world, after the Roman alphabet. It includes 28 basic letters and has a number of properties that differ from those of the Roman alphabet. It is written from right to left in a cursive style and does not have upper- and lowercase letter forms. Importantly, many of the letters look visually similar and are distinguished from one another by dots located above or below them. These dots are an integral part of the letters. For example, the Arabic letters transliterated as *b* and *t* have the same basic shape, with the difference that *b* has one dot below (ب), whereas *t* has two dots above (ت). (In all examples, we employ the Buckwalter transliteration codes.) More importantly for the present purposes, the shapes of the letters vary depending on their position within a word (see Friedmann & Haddad-Hanna, 2012, for a table of the different contextual forms in Arabic). For instance, the letter ع (*'ayn*) adopts quite different visual shapes when it is located in the initial letter position, connected to the following letter (as in علاج ["treatment," transliterated as *ElAj*]); in a middle position, connected to the previous and following letters (as in معلم ["teacher," *mElM*]); in a final position, connected to the previous letter (as in أربع ["four," > *bE*]); and when it is not connected with the preceding or following letter (as in نزاع ["dispute," *nzAE*]). Note that most letters in Arabic are connected with the preceding and following letters—when not connected, letters are presented in the canonical (isolated) form (as in نزاع). This means that a given letter may vary its visual form depending on the connective pattern of the preceding and following letters.

Thus, in Arabic, many similarly shaped letters represent different abstract letter identities, and many differently shaped letters represent the same abstract letter identity. This difficulty has an impact on the way that words are processed: Arabic speakers who have mastered Hebrew as a second language can process visually presented Hebrew letters faster and more accurately than visually presented Arabic letters (Ibrahim, Eviatar, & Aharon-Perez, 2002). This suggests that the slower performance times in Arabic seem to be due to difficulties in decoding the complex visual orthography of the letters. Furthermore, learning to read in Arabic is slower than in another Semitic language, Hebrew (Azzam, 1984), so the fact that Arabic words are harder to identify than Hebrew words seems to be the result of increased visual complexity and not of the morphological system. One possibility is that Arabic readers rely more on the physical appearance of letters than on their abstract representations. Importantly, Friedmann and Haddad-Hanna (2012) recently reported that Arabic individuals with dyslexia made a larger number of transposed-letter errors when the letter position did not change the visual form (e.g., تمهل) , "slowed" [*tmhl*] was misread as تهمل "neglect" [*thml*]), but not when the transposition changed the visual form (e.g., جهاز "device" [jhAz] was not misread as as جاهز "ready" [jAhz]). Friedmann and Haddad-Hanna claimed that "the different forms of the same letter [in Arabic] have different abstract letter identity units" or at least, that abstract letter identities might be common to a given letter "but with indication of the form they appeared in." If this is so, Arabic readers may not achieve an abstract representation of letters at the early stages of processing—or at least, this may be dependent on letter shape. Clearly, the intricacies of the orthographic system of Arabic make it particularly relevant for investigating the extent to which the properties of abstract letter representations are alphabet-specific or rather derive from a universal mechanism.

Importantly, as occurs with lowercase versus uppercase letters in the Roman alphabet, some Arabic letters look visually similar in all four positions (e.g., isolated/final/middle/beginning: e.g., ظ/ ـظ / ـظـ / ظـ all represent the letter *zā'*), while others show considerable variation (e.g., ع/ ـع / ـعـ / عـ represent the letter *'ayn*). In the present experiment, we examined whether or not the masked repetition priming effect with Arabic letters occurs to the same degree for visually similar (e.g., ـفـ and ف, which correspond to the letter fā') and for dissimilar (e.g., ـعـ and ع, which correspond to the letter *'ayn*) letters. We employed a design very similar to that used by Kinoshita and Kaplan (2008, Exp. 3), except that we used middle and isolated letters in Arabic as probes and targets rather than lower- and uppercase letters in Roman script (see Table 1 for an illustration of the experimental conditions). For simplicity, we chose the middle and isolated positions as paradigmatic cases; there is no reason why initial and final forms would behave in a different way to middle and isolated forms.

The hypotheses were straightforward. If participants access abstract letter identities at early moments of processing, the magnitudes of masked repetition priming should be equivalent for visually dissimilar stimuli (ـعـ ع ع vs. ـعـ ح ع and ع ـعـ ـعـ vs. ع ـحـ ـعـ) and for visually similar stimuli (ـظـ ظ ظ vs. ـظـ ر ظ and ظ ـظـ ـظـ vs. ظ ـر ـظـ), as actually occurs with the lowercase/uppercase distinction in the Roman alphabet (Kinoshita & Kaplan, 2008). This finding would suggest that participants rely on abstract letter representations, regardless of case (lowercase/uppercase for the Roman alphabet) or letter position (isolated/middle for the Arabic alphabet). In contrast, if the level of abstract letter identity in Arabic still includes letter form information from the first stage of orthographic–visual analysis (as claimed by Friedmann & Haddad-Hanna, 2012), the magnitude of masked repetition priming should be greater for those letters that look visually similar in their isolated and middle forms than for those that look dissimilar. The latter finding would imply that priming of abstract letter representations is not universal, or at least that, on top of abstract letter identity, letter visual similarity contributes in a significant way to letter recognition.

Method

Participants

A group of 39 college students at the École Supérieure Roi Fahd de Traduction at Tangier (Morocco) and at the Universidad Politécnica in Valencia (Spain) took part in the experiment voluntarily. They were native speakers of Arabic, had studied in primary and secondary school in their home countries, and used Modern Standard Arabic on a daily basis. All of them had normal or corrected-to-normal vision.

Materials

We selected four Arabic letters that look perceptually dissimilar when written in their middle and isolated forms (ـعـ / ع, ـحـ / ح, ـكـ / ك, and ـمـ / م) and four Arabic letters that look perceptually similar when written in their

Table 1 Examples of probe–prime–target triplets employed in the experiment

Response type	Letter type	Prime type: Identity	Prime type: Control
Same	Dissimilar	ـعـ ع ع, ع ـعـ ـعـ	ـعـ ح ع, ع ـحـ ـعـ
	Similar	ـظـ ظ ظ, ظ ـظـ ـظـ	ـظـ ر ظ, ظ ـر ـظـ
Different	Dissimilar	ـمـ م ع, ح ـحـ ـعـ	ـكـ م ع, م ـكـ ـعـ
	Similar	ـر ر ظ, ر ـر ـظـ	ـد د ظ, ف ـفـ ـظـ

isolated and middle forms (ـظـ / ظ , ـفـ / ف , ـد / د , and ـر / ر). We chose these letters as “similar” or “dissimilar” on the basis of a pilot study conducted with Spanish students (with no knowledge of Arabic letters) at the University of Valencia: These participants rated (on a 1–7 Likert scale) the perceptual similarity across a large number of pairs of Arabic letters. In all cases, the probe and the target were in different letter forms (i.e., in half of the cases isolated–middle, and in the other half middle–isolated). Similar to Kinoshita and Kaplan’s (2008) Experiment 3, the prime was always in the same letter form as the target. We created 32 probe–prime–target triplets in which the probe and the target were the same (half of them with visually similar letters) and 32 probe–prime–target triples in which the probe and the target were different (half of them with visually similar letters). For “same” trials, we manipulated the prime–target relationship (same vs. different), the prime type (similar vs. dissimilar letter), and target type (middle vs. isolated letter); for “different” trials, we manipulated the probe–prime relationship (same vs. different), the prime type (similar vs. dissimilar letter), and the target type (middle vs. isolated letter). Note that we manipulated the probe–prime relationship rather than the prime–target relationship in order to have a zero prime–target contingency (see Kinoshita & Kaplan, 2008, Exp. 3). To avoid physical continuity, the prime was presented in 12-point Arabic font, and the probes and targets were presented in 22-point Arabic font (e.g., ـعـ ع ع). A list of examples for the different experimental conditions is provided in Table 1. Given that the complete set of stimuli yielded 64 trials (32 “same” and 32 “different” trials), and to increase the sample size (and the experimental power), we conducted the experimental blocks three times (i.e., 192 trials overall). The order of the trials was completely randomized for each participant.

Procedure

The participants were tested individually or in groups of two in a quiet room. Presentation of the stimuli and recording of the response times were controlled by Windows computers running DMDX (Forster & Forster, 2003). On each trial, a reference (probe) letter was presented above a forward mask consisting of a series of hash marks (#s) for 1,000 ms. Then the probe disappeared, and the forward mask was replaced by a prime for 50 ms—which was then replaced by the target stimulus at the same location. The target stimulus remained on the screen until the participant’s response. Participants were told that they would see two letters in Arabic (i.e., a probe and a target), that they should press a button labeled “same” if they thought that the probe and the target were the same stimulus, regardless of letter form (i.e., ـعـ and ع would correspond to a “same” response), and that they should press a button labeled “different” if they thought that the probe and the target were different stimuli. They were instructed to make this decision as quickly and as accurately as possible. The participants reported not having seen any prime stimuli when they were asked after the experiment. Each participant received a different random order of the stimuli, as well as a total of 20 practice trials prior to the experimental phase. The session lasted approximately 15 min.

Results

Incorrect responses (6.7 % of the data) and response times less than 250 ms or greater than 1,200 ms (less than 2.8 % of the data) were excluded from the response time analyses. The mean response times and error percentages from the participant analysis are presented in Table 2. For “same” trials, analyses of variance (ANOVAs) based on the participant and item mean correct response times were conducted on the basis of a 2 (prime type: similar or dissimilar) × 2 (prime–target relatedness: identity or control) × 2 (target type: isolated or middle) design. (For “different” trials, the design was the same, except that we manipulated the probe–prime relationship rather than the prime–target relationship.) As is usual, “same” and “different” responses were analyzed separately (see Kinoshita & Kaplan, 2008).

Table 2 Mean response times (in milliseconds) and percentages of errors (in parentheses) in the experiment

	Type of Letter	
	Dissimilar	Similar
“Same” Responses		
Isolated targets		
Identity	574 (6.4)	580 (5.6)
Control	601 (5.8)	599 (6.0)
Priming (C–I)	27 (−0.6)	19 (0.4)
Middle targets		
Identity	599 (6.2)	589 (6.6)
Control	623 (8.8)	609 (7.5)
Priming (C–I)	24 (2.6)	20 (0.9)
“Different” Responses		
Isolated targets		
Identity	664 (6.0)	649 (6.8)
Control	659 (6.0)	641 (6.0)
Priming (C–I)	−5 (0.0)	−8 (−0.8)
Middle targets		
Identity	682 (7.9)	648 (7.3)
Control	683 (7.3)	657 (6.4)
Priming (C–I)	1 (−0.6)	9 (−0.9)

"Same" responses

The ANOVA on the latency data showed that responses to targets were, on average, 23 ms faster when the prime was identical to the target than when it was a control letter, $F_1(1, 38) = 33.27$, $MSE = 1{,}187$, $p < .001$; $F_2(1, 12) = 22.53$, $MSE = 208.9$, $p < .001$, and that responses to targets were, on average, 16 ms faster for isolated letters than for middle letters, $F_1(1, 38) = 12.67$, $MSE = 1{,}665$, $p < .002$; $F_2(1, 12) = 4.58$, $MSE = 413.6$, $p = .054$. The other effects or interactions did not approach significance—in particular, the F ratios corresponding to the Prime Type × Relatedness × Target Type interactions were both $F < 1$. Indeed, the effects of relatedness were very similar in size for visually similar and for visually dissimilar letters (if anything, the effect was in the reverse direction from the one expected: 20 vs. 25 ms; the critical F ratio for the Prime Type × Relatedness interaction was less than 1),[1] and they were also similar in magnitude for isolated and middle letters (23 vs. 22 ms).

The ANOVA on the error data did not reveal any significant effects.

"Different" responses

The ANOVA on the latency data showed that responses to similar-type letters were, on average, 23 ms slower than responses to dissimilar-type letters, $F_1(1, 38) = 24.46$, $MSE = 1{,}690$, $p < .001$; $F_2(1, 12) = 14.92$, $MSE = 313.0$, $p < .003$, and that responses to targets were, on average, 14 ms faster for isolated than for middle letters, $F_1(1, 28) = 8.17$, $MSE = 1{,}936$, $p < .008$; $F_2(1, 12) = 4.01$, $MSE = 313.0$, $p = .068$. The other effects and interactions were not significant (all ps > .13).

The ANOVA on the error data did not reveal any significant effects.

Discussion

To what degree do the units in visual-word recognition differ across orthographies? To discover this, it will be important to examine which phenomena vary across orthographic systems and which phenomena remain invariant. In the present experiment, we examined whether priming of abstract letter identities takes place in Arabic—an orthographic system in which letter shape varies according to letter position and is also modulated by the connectivity patterns of the neighboring letters. The magnitudes of masked repetition priming were equivalent for visually similar and for visually dissimilar letters in their middle and isolated forms, thus demonstrating that priming of abstract letter identities does occur in Arabic.

The present data are consistent with the findings obtained by Kinoshita and Kaplan (2008) with the Roman alphabet in a cross-case letter match task (i.e., similar priming for a–A and c–C). Likewise, the present data are also consistent with previous findings obtained by Kinoshita and Norris (2009) using the masked priming same–different task with English words: They showed that during word identity priming, the featural similarity of the prime and target letters had no impact on the size of masked repetition priming (i.e., similar repetition priming for *kiss–KISS* and *edge–EDGE*).

In the present experiment, as in Kinoshita and Kaplan (2008, Exps. 2–3), the identity prime and the target for "same" trials were always the same except for font size (e.g., as in ـعـ ع ع). Thus, one could argue that, regardless of the visual similarity between probes and targets (e.g., ـظ ظ ظ vs. ـعـ ع ع), an identity prime preactivated the target letter's shape representation, and this would produce faster access to the representations/processes that allowed a "same" decision, which an unrelated prime would not. Given that the underlying mechanisms in the cross-case (or cross-position) same–different task do not seem to be phonological (see Norris & Kinoshita, 2008), the most likely possibility is that these representations/processes are abstract letter representations. Nonetheless, we acknowledge that a stronger demonstration of the activation of abstract letter identities would be to obtain an advantage of ـعـ ع ـعـ versus the control ـعـ ح ـعـ in Arabic (or a–A–a vs. a–B–a in the Roman alphabet). Norris and Kinoshita conducted such an experiment with the Roman alphabet and found masked repetition priming for visually similar letters (c–C–c faster than c–B–c), but not for visually dissimilar letters (similar response times to a–A–a and a–B–a). Norris and Kinoshita indicated that, in this case, the decisions occurred "at the level of case-specific letter identity" rather than "at the level of abstract letter identity." We conducted a parallel experiment in Arabic and replicated the findings of Norris and Kinoshita.[2] Although the null priming effect for visually dissimilar letters under those circumstances (i.e., when probes and targets had the same case/position) may be observed as a key limitation of this technique, it also reveals that the effects obtained in a cross-

[1] The values of $p(H_0/D)$ were .84 and .76 for the F_1 and F_2 analyses, respectively, thus providing support for the null hypothesis (Masson, 2011).

[2] To reexamine this issue in Arabic, we conducted an experiment with 20 native speakers of that language. The materials were the same as in the present experiment, except that probes and targets were always in the same letter position (either middle or isolated), while the prime was in the other position (e.g., ـه ـهـ هـ ه vs. ـع ـعـ عـ ع for visually dissimilar letters; ـغ ـغـ غـ غ vs. ـعـ ع ـعـ for visually similar letters). Similarly to Norris and Kinoshita (2008), we found masked repetition priming for visually similar letters (21 ms), but not for visually dissimilar letters (−1 ms).

position (or cross-case) masked priming same–different task are abstract in nature. Finally, a highly promising strategy to examine abstract letter representations is to employ letters in which the probe, prime, and target are *all* visually different. The constraint here is that only three Arabic letters are visually different in (at least) three positions (i.e., *hā'*, ـعـ ح ـعـ; *'ayn*, ظ ظ ظ; and *ghayn*, ظ ـر ظ), and two of them resemble each other. Further research should be devoted to disentangle the (potential) early effects of letter form and the later effects of abstract letter identities.

Clearly, years of reading allow our cognitive system to process letters (i.e., familiar objects with distinctive shapes) in a highly efficient manner. Although the development of these perceptual skills may vary across alphabets (Azzam, 1984), once settled as abstract letter representations, these units are hardly modulated by increased exposure to print. The data from Friedmann and Haddad-Hanna (2012) suggest that, at least for readers with dyslexia, letter form information is encoded as part of the abstract letter identity during the recognition of Arabic words. However, it is critical to examine whether the level of abstract letter identity still includes letter form information from the first stage of orthographic–visual analysis in the Arabic reading system with normal skilled readers (see Lavidor, 2011, for evidence of whole-word shape effects in English words with readers with dyslexia, but not with a control group).

In sum, priming of abstract letter identities occurs in an alphabet, Arabic, with an intricate letter system. Thus, despite the fact that the weights of orthographic/phonological processes across languages and alphabets may vary depending on the particular grapheme-to-phoneme mapping arrangements (Ziegler & Goswami, 2005), the present data support the view that priming of abstract letter representations is a universal phenomenon.

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