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# Morphology, orthography, and the two hemispheres: A divided visual field study with Hindi/Urdu biliterates

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ABSTRACT

Although identical on the spoken level, Hindi and Urdu differ markedly on the written level in terms of reading/writing direction and orthographic depth, with discernible processing consequences. The present study used a divided field paradigm to study the impact of writing system characteristics of Hindi and Urdu on word naming latencies in skilled biliterate users of these languages. Hindi (read/written from left to right) was hypothesized to show a larger right field advantage than Urdu (read/written from right to left); Hindi words sharing form overlap with primes were expected to show a significant priming effect in the left visual field, but a significant right field effect for morphologically-primed naming. Both these expectations were confirmed. An overall right field advantage was obtained for one syllable Hindi and Urdu words; two syllable Urdu words showed either no visual field differences or a left field advantage, and the right field advantage for Hindi was significantly greater for two syllable than one syllable words. Further, Hindi words showed significant form priming (relative to control stimuli) in the left visual field and significant morphological priming (relative to form priming) in the right visual field. By contrast, Urdu words showed no significant form priming in either visual field, and significantly greater morphological than form priming in the left visual field. These results are taken to suggest that visual field asymmetries in word naming are sensitive to differences in reading habit-related scanning biases and to orthographic depth-related differences in word recognition processes.

## 1. The problem – morphology, orthography and the two hemispheres

Studies on languages with concatenative (stem and affix) type of morphology, such as English, suggest that the left hemisphere (LH) is more sensitive than the right hemisphere (RH) to the processing of derived or inflected words. However, a special role of the RH has been claimed for languages with richer morphological structure, such as Finnish, and for languages with non-concatenative (root and verbal pattern) morphology, such as Hebrew or Arabic.

Given that Hebrew and Arabic differ from English or Finnish not just in morphology but also in orthographic properties, it is possible that some of the hemispheric processing differences attributed to morphology may reflect differences in word recognition strategies arising from orthographic depth differences across languages. The present research explored this possibility by studying visual field asymmetries in word naming in Hindi and Urdu. These languages present a unique opportunity to examine the contribution of orthographic properties since they are practically identical in their morphophonology (as well as in their grammar and lexicon), but are written in completely different orthographies (see also Ahmad, 2008; Rao et al., 2014). As such, it becomes possible to isolate for study the contribution of orthographic differences, while keeping other linguistic differences constant.

### 1.1. Hemisphere differences in word recognition

Before turning to our research, a brief overview of hemispheric asymmetries in word recognition is provided. The relative contribution of the left and the right cerebral hemispheres to language processing has interested researchers for over a century and has led to an explosion of studies examining functional hemispheric asymmetries, initially using behavioral methods such as visual hemifield presentation or dichotic listening. Behavioral asymmetries in language dominance have been corroborated by findings from neuroimaging studies (e.g., Hunter and Brysbaert, 2008), and neuroimaging studies are increasingly examining asymmetries in brain activation.

Divided visual field studies have consistently shown a right visual

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field advantage for visual word recognition across a range of tasks including word naming, lexical decision, and semantic relatedness judgements (e.g., Willemin et al., 2016). Although visual field asymmetries in word naming or other verbal judgments are typically taken to imply hemisphere differences in language processing, it is acknowledged that behavioral asymmetries may also be influenced by a number of other factors as well.

For example, visual field asymmetries have been known to be influenced by input characteristics, stimulus characteristics, presentation conditions, task demands, and participants' language experience. Input characteristics include properties affecting spoken language (phonology, stress patterns, tonality, etc.), characteristics of signed language (spatial aspects) and properties of written language (visuospatial complexity, script direction, orthographic depth). Stimulus characteristics relate to aspects of the unit of study (single letters, numerals, words, phrases, sentences, discourse). Input presentation variables include the level of illumination, or stimulus exposure duration. Task demands refer to the type of component processing called for by the task, which may interact with the level at which the language is being addressed, e.g., orthographic, phonological, morphological, semantic, syntactic, or pragmatic. Finally, experience related variables include the language user's linguistic history and pattern of language use (single or multiple language user, early or late onset of bilingualism, and formal or informal context of language use), as well as their level of literacy in a language, and/or their experience with specific orthographies. Thus, asymmetries in performance are subject to multiple influences, making it important to systematically test different potential sources of influence before generalizations can be made.

### 1.2. Phonological vs. orthographic processing and hemisphere differences

Of interest to the present research is how orthographic knowledge specific to a particular language may affect hemispheric differences in the processing of different dimensions of language, such as phonology, semantics, or morphology. Although there is a sizeable literature on hemispheric involvement in these different aspects of language, less is known about the contribution of writing system characteristics in relation to these dimensions.

Several studies have demonstrated differential hemispheric involvement in the phonological vs. surface (visual) processing of visually presented words. For example, Vaid (1984, 1987) demonstrated a right visual field advantage on a rhyme judgment task in which surface matching would lead to errors and phonological processing would be required for successful performance (e.g., LINT/PINT; SEW/SOW); however, when rhyme judgments could successfully be performed on the basis of surface cues alone (e.g., LINT/MINT), a left visual field advantage was found (see also Lavidor and Ellis, 2003).

While the evidence points to a consistent left hemisphere advantage in word recognition, particularly when phonology is the salient dimension being tapped, this effect may be moderated by the degree to which the writing system of a language is phonologically transparent. In languages with so-called 'deep' orthographies, such as Mandarin, Japanese kanji, Hebrew, Persian, or Urdu, the degree of left hemispheric asymmetry in lexical processing may be reduced. For example, a study by Melamed and Zaidel (1993) of lateralized word naming and lexical decision among readers of Farsi (Persian), which is written in a Perso-Arabic script, found no visual field asymmetries, in contrast to a right field advantage in native English readers. The authors concluded that there may be more RH involvement in word recognition in Farsi than in English. Of course, it is difficult to know how exactly to interpret a lack of visual field difference.

Studies conducted on non-alphabetic orthographies such as Chinese or Japanese have similarly shown attenuated hemispheric functional asymmetries in word recognition, particularly in tasks involving visual processing of words. For example, homophone and semantic categorization judgments showed a clear RVF advantage, but judging whether a character had a legal configuration or was an inverted image of an actual character showed no visual field asymmetry in readers of Chinese (Leong et al., 1985). Yang and Cheng (1999) replicated the finding of a RVF advantage for homophone judgments in Chinese but reported a significant left visual field advantage for orthographic similarity judgments. Similarly, Vaid and Park (1997) found visual vs. phonological task-related differences in laterality patterns in readers of Korean. And studies with Japanese readers have shown that words written in the syllabic script, Kana, interfere more when they were presented as distractors in the RVF, whereas the visuospatially more complex Kanji script exercises a greater interference effect when presented to the LVF (Hatta et al., 1983; Yamaguchi et al., 2002).

### 1.3. Morphological processing: left hemisphere specialization

In contrast to the number of laterality studies that have examined the processing of phonological, visual, or semantic characteristics of words, relatively few studies have examined hemisphere differences in morphological processing. This is particularly surprising given the abundance of psycholinguistic and neurocognitive studies on the processing of inflected and derived words in users of a variety of languages. Given the fact that (especially in concatenative morphology languages) morphologically related words are also related in form and meaning, a major focus of studies on morphological processing has been to examine whether morphology has a separate existence in the mental lexicon, independent of form or meaning relations (e.g., Feldman, 2000; Bozic et al., 2007; Dominguez, 2004). In addition, studies have examined the time course of morphological priming effects in relation to form or semantic priming effects (e.g., Feldman et al., 2009; Rao, 2010), and neural correlates of morphological processing in relation to orthographic and semantic processing. There has also been considerable interest in showing whether morphological processing differs in users of typologically different languages.

Although these issues are not fully resolved, there is agreement that morphology has a functional presence in the mental lexicon and that there are distinct patterns of neural activation associated with morphological processing, separable from those involved in processing other dimensions of language that may overlap with morphological distinctions (e.g., form or meaning). For example, whereas one study did not find brain regions dedicated to morphology (Devlin et al., 2004), other studies, conducted with users of English, Finnish, German, Italian, Hebrew, Arabic, and Spanish, have found evidence of activation exclusive to morphological processing (e.g., Bick et al., 2011; Cavalli et al., 2016; Gold and Rastle, 2007), associated with regions in the left hemisphere. Moreover, there is now robust evidence suggesting differences in morphological processing across languages as a function of whether the language supports a stem and affix or a root and verbal pattern type of morphological structure (see Boudelaa and Marslen-Wilson, 2015, for an overview of morphological priming studies with Arabic and Hebrew). What is less clear from existing neuroimaging studies is whether the brain regions activated in response to morphological processing are predominantly left hemisphere dominant, as some evidence for bilateral activation has also been noted.

With respect to behavioral laterality investigations, the few existing studies show evidence for left hemisphere superiority in morphological processing. For example, Burgess and Skodis (1993) compared lexical decision for *morphologically ambiguous* verbs (defined as verbs that belong to two syntactic categories) and *unambiguous* verbs (those belonging to one syntactic category) in hemifield presentation. Results showed significantly faster responses to ambiguous than unambiguous verbs, but only for items presented to the RVF/LH. The two types of