

MORPHOLOGY IN WORD RECOGNITION: HINDI AND URDU

A Dissertation

by

CHAITRA RAO

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

May 2010

Major Subject: Psychology

MORPHOLOGY IN WORD RECOGNITION: HINDI AND URDU

A Dissertation

by

CHAITRA RAO

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of
DOCTOR OF PHILOSOPHY

Approved by:

Chair of Committee,	Jyotsna Vaid
Committee Members,	Heather Bortfeld
	Irene Moyna
	Lou Tassinary
Head of Department,	Les Morey

May 2010

Major Subject: Psychology

ABSTRACT

Morphology in Word Recognition: Hindi and Urdu. (May 2010)

Chaitra Rao, Bac.; M.A.; PhD, University of Mysore

Chair of Advisory Committee: Dr. Jyotsna Vaid

The present research examined whether morphology influences word recognition independently of form-level word properties. Prevailing views attribute cross-linguistic differences in morphological processing to variations in morphological structure and/or productivity. This study tested whether morphological processing is additionally influenced by the orthographic depth of written language, by comparing primed word naming among biliterate readers of Hindi and Urdu, languages written in distinct orthographies but sharing a common morphophonology. Results from five experiments supported the view that morphological processing in orthographically shallow (transparent) Hindi script diverged significantly from that in the deeper (opaque) Urdu orthography.

Specifically, morphological priming was differentially affected in Hindi vs. Urdu by prime presentation conditions (Exps. 1 – 3): very briefly exposed (48ms), forward masked morphological primes facilitated word naming in Hindi but not in Urdu. Neither briefly presented, unmasked primes nor longer prime exposures (80ms/240ms) produced priming in Hindi, but Experiment 2 showed priming by unmasked Hindi

primes at a 240ms exposure. By contrast, Urdu exhibited morphological priming only for forward masked primes at the long exposure of 240ms. Thus, early-onset priming in Hindi resembled morpho-orthographic decomposition previously recorded in English, whereas Urdu evinced priming consistent with morpho-semantic effects documented across several languages.

Hemispheric asymmetry in morphological priming also diverged across Hindi and Urdu (Exps. 4 and 5); Hindi revealed a non-significant numerical trend for facilitation by morphological primes only in the right visual field (RVF), whereas reliable morphological priming in Urdu was limited to left visual field (LVF) presentation. Disparate patterns in morphological processing asymmetry were corroborated by differences in baseline visual field asymmetries in Hindi vs. Urdu word recognition—filler words elicited a consistent RVF advantage in Hindi, whereas in Urdu, one-syllable fillers, but not two- and three-syllable words revealed the RVF advantage.

Taken together, the findings suggest that the variable of orthographic depth be integrated more explicitly into mainstream theoretical accounts of the mechanisms underlying morphological processing in word recognition. In addition, this study highlights the psycholinguistic potential of the languages Hindi and Urdu for advancing our understanding of the role of orthography as well as phonology in morphological processing.

ACKNOWLEDGMENTS

I would like to thank the members of my committee for a rewarding graduate school experience. Thanks to Heather Bortfeld and Lou Tassinary for co-teaching a fascinating and fun class on neuroscience and architecture—their class not only provided me with knowledge on neuropsychological assessment techniques, it also sharpened my desire to explore the neural underpinnings of language processing. I am grateful likewise to Irene Moyna, who, in addition to being extremely encouraging and supportive, stimulated me to consider this research from a fresh perspective that incorporated much-needed linguistic and sociocultural depth. The committee’s feedback throughout the research process, including the preliminary defense of the literature review and research proposal, as well as on the draft dissertation itself, has been invaluable in helping me to clarify the logic as well as methodology of my research.

Most of all, I would like to say “thank you” to Jyotsna Vaid, my advisor, whose focus, enthusiasm and sheer energy have been a great motivation through the years. Her uncompromising insistence on lucidity, in thought as well as in expression, combined with her unstinted support at every step of the research process, enabled me to aim higher and strive harder in my work. Having found her mentorship to be a personally as well as professionally enriching experience, I can truly say that I am fortunate to have been one of her students.

Thanks also to Narayanan Srinivasan, who graciously made available the facilities at the Centre for Behavioural and Cognitive Sciences in Allahabad for testing participants, and who sustained me during the difficult and demanding period of data collection with his warm hospitality and his ready and timely advice on everything from experimental procedure to administrative hurdles. My sincere thanks also to the remaining faculty, staff and students of CBCS for making me feel at home, and for myriad kindnesses they showed me during my stay in Allahabad.

The Urdu speaking population of Allahabad welcomed me into their homes and their hearts, and volunteered their time and effort to participate in my experiments—for their unreserved acceptance and large-hearted generosity, I am extremely grateful. To Atiya Nishat Khan especially, many thanks for offering me hope and encouragement at a particularly difficult juncture, and for introducing me to Younus Siddiqui, who is in many ways more deserving of this doctoral degree than me. For their warm friendship and support, I thank Nasra, Farzana and Azra Rizvi, Samudragupta Bora, Laique Ahmad Siddiqui and Abdul Quadir. A special “thank you” is due also to Richa Singh, for her wonderful diligence and patience in assisting with my data collection.

I am greatly indebted to my fellow graduate students, Hsin-Chin Chen and Na Yung Yu. My heartfelt gratitude to Hsin-Chin Chen for mentoring me and teaching me almost everything I know about

experimental design and analysis, as well as for his forbearance and kindness in the role of expert advisor into which I have continually cast him. To Na Yung Yu, my deepest thanks for being so much more than a friend – for caring, comfort, championship, criticism and camaraderie – in short, for walking the path with me.

I owe this degree also to the friends and family who made it possible for me to stay the course. I thank Wookyoung Jung, Nicholas Simon, Srikanth Sastry, Arun Surendran and Michael ‘Doc G’ Greenwald, for stimulating company and conversations, and to the latter two for the blessed escape of theater. A big “thank you” to Purnima and Srinivas Kulkarni for refreshing breaks and generous gifts that went a long way in smoothing the rough edges, and to Mahesh Rao for sparing precious time and much effort to visit with me, and for prodding me gently to finish.

My real and adopted family has been a steadfast anchor and an unfaltering source of strength, and for this I am very grateful. Younus Siddiqui taught me Urdu, gave me help and advice in selecting and preparing stimuli, and worked untiringly to coax and cajole would-be participants—his limitless enthusiasm and indefatigable spirit have been a source of inspiration, while his affection, compassion and giving spirit have led me to count him among my family. And finally, I have drawn on the constant encouragement, humorous relief, and most importantly, on the boundless faith of Kumar Bhat, and Usha, Umesh, and Chetan Rao.

TABLE OF CONTENTS

	Page
ABSTRACT	iii
ACKNOWLEDGMENTS	v
TABLE OF CONTENTS	viii
LIST OF FIGURES	xi
LIST OF TABLES	xiii
INTRODUCTION	1
Morphology: Definition, Mental Representation and Processing	4
Reconsidering the Role of Form and Meaning: A Two-Stage Approach	11
Morphological Processing as a Function of Morphological Structure	15
Morphological Processing as a Function of Morphological Productivity	18
Morphological Structure vs. Productivity: Unresolved Questions	21
Reconciling the Differences: The Role of Orthographic Depth	24
DOES ORTHOGRAPHIC DEPTH MEDIATE MORPHOLOGICAL PROCESSING? THE CASE OF HINDI AND URDU	28
Brief Historical Overview of Hindi and Urdu	28
Orthography vs. Morphology in Hindi/Urdu	29
Orthographic Depth and Word Recognition in Hindi vs. Urdu	33
The Present Study	34
EXPERIMENT 1: TIME COURSE OF MORPHOLOGICAL VS. FORM PRIMING IN NAMING HINDI VS. URDU WORDS	36
Method	37
Results	40
Discussion	46

	Page
EXPERIMENT 2: TIME COURSE OF MORPHOLOGICAL VS. FORM PRIMING IN NAMING HINDI VS. URDU WORDS UNDER UNMASKED CONDITIONS	52
Method	53
Results	54
Discussion	58
EXPERIMENT 3: ROLE OF MASKING AND FORM OVERLAP IN HINDI AND URDU MORPHOLOGICAL PRIMING	62
Method	66
Results	69
Discussion	77
GENERAL DISCUSSION	83
HEMISPHERIC ASYMMETRY IN MORPHOLOGICAL PROCESSING	95
Left Hemisphere Dominance in Visual Word Recognition	97
Orthographic Depth and Right Hemisphere Involvement	99
Left Hemisphere Specialization for Morphological Processing	102
Right Hemisphere Capacity for Morphological Processing	105
DOES ORTHOGRAPHIC DEPTH MODULATE MORPHOLOGICAL PROCESSING ASYMMETRY IN HINDI AND URDU?	108
EXPERIMENT 4: LATERALIZED LONG-TERM MORPHOLOGICAL PRIMING OF HINDI AND URDU MONOSYLLABIC WORDS	113
Method	114
Results	116
Discussion	121
EXPERIMENT 5: LATERALIZED LONG-TERM MORPHOLOGICAL PRIMING OF HINDI AND URDU	

	Page
POLYSYLLABIC WORDS	126
Method	126
Results	127
Discussion	131
GENERAL DISCUSSION	136
CONCLUSIONS AND FUTURE DIRECTIONS	142
Implications for Models of Morphology	144
Significance to Research on Hemispheric Asymmetry	145
Psycholinguistic Value of Hindi and Urdu	146
Ancillary Findings	151
Broader Impact	152
REFERENCES	154
APPENDIX A: HINDI & URDU ALPHABETS WITH PHONETIC SYMBOLS	185
APPENDIX B: PRIME-TARGET PAIRS USED IN EXPERIMENTS 1, 2 & 4	188
APPENDIX C: PRIME-TARGET PAIRS USED IN EXPERIMENTS 3 & 5	200
APPENDIX D: ANOVA TABLES	208
VITA	212

LIST OF FIGURES

FIGURE	Page
1 Morphological representation in the satellite entries approach (e.g., Caramazza, Laudanna & Romani, 1988). The root morpheme forms the central node, and derivations are represented as auxiliary nodes.....	9
2 Morphological representation and processing in Frost et al.'s (1997) model. All words formed from a common root morpheme are linked to the root, facilitating mutual activation among morphologically transparent as well as opaque relatives. [Figure adapted from Frost et al. (1997).].....	17
3 Phonetic transcriptions of Hindi/Urdu sentences illustrating gender derivations ('boy' vs. 'girl'), as well as number ('boy' vs. 'boys') and case inflections (direct vs. of oblique forms 'boys') of a single noun, as also noun – verb agreement in Hindi/Urdu (the verb form of 'was' agrees with gender and number of the noun in each case).	30
4 Orthographically distinct representation of a single word in Hindi (Devanagari script) and Urdu (Perso-Arabic script).	33
5 Mean naming latencies in Exp. 1 as a function of Script, Prime Type, and SOA; priming relative to control (ctrl) indicated by ** (participants and item ANOVA) and * (participant ANOVA only); superiority of morphological (morph) vs. form-overlap (form) condition in the ANOVA by-participants indicated by Σ ($p < .10$).	44
6 Participants' mean naming latencies for Hindi and Urdu under unmasked priming conditions as a function of SOA and Prime Type (Exp. 2); priming ($p < .004$) relative to control indicated by ** (participant and item ANOVA) and * (ANOVA by-participants or by-items only).	58

FIGURE	Page
7 Combined graphs of participants' Reaction Time (left y-axis, column graphs) and accuracy (right y-axis, line graphs) in Exp. 3; first two panels above show 48ms SOA, with performance in Hindi (top) and Urdu (bottom)	74
7 (continued) third and fourth panels show performance at 240ms SOA	75
8 Exps. 4 & 5: Participants' naming latencies to one, two and three syllable Hindi and Urdu words in morphological (morph), form-overlapping (form) and control (ctrl) conditions within right (RVF/LH) and left visual fields (LVF/RH). Significant priming relative to control indicated by * (.05); superiority of morphological over form condition indicated by ✕ (.05).	132

LIST OF TABLES

TABLE		Page
1	Example of Prime-Target pair used in Experiments 1, 2 and 4	40
2	Exp. 1: Participants' word naming latency (RT) and proportion accuracy to Hindi vs. Urdu targets preceded by morphologically-related (Morph), form-overlapping (Form) and unrelated (Control) primes (n = 92)	42
3	Exp. 2: Participants' word naming latency (RT) and proportion accuracy to Hindi vs. Urdu targets preceded by morphologically-related (Morph), form-overlapping (Form) and unrelated (Control) primes (n = 32)	56
4	Example of Prime-Target pair used in Experiments 3 and 5	67
5	Exp. 3: Participants' word naming latency (RT) and proportion accuracy to Hindi vs. Urdu targets preceded by masked vs. unmasked morphological (Morph), form-overlapping (Form) and unrelated (Control) primes (n = 81)	71
6	Exp. 4: Participants' word naming latency (RT) and proportion accuracy in right vs. left visual field (RVF/LH vs. LVF/RH) presentations of Hindi vs. Urdu filler words (n = 26)	117
7	Exp. 4: Participants' word naming latency (RT) and proportion accuracy in right vs. left visual field (RVF/LH vs. LVF/RH) presentations of Hindi vs. Urdu targets cued by morphological (Morph), form-overlapping (Form) and unrelated (Control) primes (n = 26)	121
8	Exp. 5: Participants' word naming latency (RT) and proportion accuracy in right vs. left visual field (RVF/LH vs. LVF/RH) presentations of Hindi vs. Urdu filler words (n = 23)	129

TABLE	Page
9 Exp. 5: Participants' word naming latency (RT) and proportion accuracy in right vs. left visual field (RVF/LH vs. LVF/RH) presentations of Hindi vs. Urdu targets cued by morphological (Morph), form-overlapping (Form) and unrelated (Control) primes (n = 23).....	130

INTRODUCTION

Evidence drawn from a number of languages shows that visual recognition of words presented in isolation is influenced by phonological, orthographic, and semantic/syntactic characteristics of the words. Whereas considerable attention in psycholinguistics has been directed at understanding the relative contribution of these dimensions, there has been growing interest in recent years in investigating the potential contribution of the dimension of morphology.

Demonstrating that the morphemic structure of a word may have a distinct status in the mental lexicon separable from representations of its sound, spelling, or meaning is complicated as words that differ in morphology also typically differ in their sound/spelling and/or meaning, at least in languages such as English. Researchers have tackled this methodological challenge by devising different techniques (such as long-lag priming or masked priming) that attempt to disentangle the overlapping influence of form-overlap and semantic relatedness, and by conducting cross-linguistic studies using languages (e.g., Hebrew vs. English) that differ systematically in ways that permit one to isolate the role of morphological characteristics. The present research employed both of these strategies in order to examine the role and time course of

morphological processing in word recognition.

Contemporary psycholinguistics takes the view that morphological characteristics that differ across languages, such as morphological structure (or type) and/or morphological productivity (or richness), shape the cognitive strategies used by readers in extracting morphological information during visual word recognition. By contrast, the research presented here will suggest that the orthographic depth of the writing system used by the language also makes an important contribution to the processing of morphological information in a given language. *Orthographic depth*, otherwise referred to as *phonological transparency*, describes the directness of mapping between spoken and written units within a language. To distinguish the influence of orthographic depth in lexical processing from the influence of morphological, phonological and lexico-semantic factors, the current study exploits the unique situation characterized by the Indic language pair Hindi and Urdu: these languages have a common morphophonological identity, lexicon, and grammar but are written in markedly different scripts which differ in orthographic depth.

The hypothesis that orthographic depth shapes morphological processing strategy is examined in two ways — by considering how orthographic depth mediates morphological priming in Hindi and Urdu word recognition (Experiments 1, 2 and 3), and by considering how

orthographic depth modulates patterns of cerebral hemispheric asymmetry for Hindi and Urdu in processing morphological information (Experiments 4 and 5).

To provide a rationale for Experiments 1 to 3, an overview of research findings on the cognitive representation and processing of morphology in various languages is first presented, with a focus on unresolved questions and issues. Following this, an outline of the concept of orthographic depth and its implications for word recognition in different languages is provided. Experiments 1, 2 and 3 are then described and discussed. The subsequent section includes a brief overview of relevant research on cerebral hemispheric asymmetry or *lateralization* of word recognition; the review outlines the relative role of the left and right cerebral hemispheres in single word recognition, especially morphological processing, and draws attention to the role of orthographic depth in modulating hemispheric asymmetry in lexical processing. Experiments 4 and 5 are presented in the penultimate section, and finally, the overall findings of this research are summarized and discussed for their implications for current theories and future research.

Morphology: Definition, Mental Representation and Processing

Morphology refers to the study of the internal structure of words and the rules by which words are formed. As commonly defined, a morpheme is the smallest sound-meaning linguistic unit with a defined function (Aronoff & Fudeman, 2004). Some morphemes (free morphemes) may stand alone, constituting words by themselves, for example open class or content words such as *hand*, *walk*, or *tall*, whereas bound morphemes (e.g., affixes) cannot stand alone, for example, *-s*, *-ed* and *-er*, in *hands*, *walked* and *taller*, respectively. Morphologically complex words contain a root and one or more affixes (Iacobini, 2008). A root refers to a lexical content morpheme that cannot be further analyzed into smaller parts, for example, *ceive* in *deceive*, or *paint* in *painter*. A stem refers to a root morpheme when it is combined with an affix; it may or may not be a word (e.g., *painter*, or *-ceive*).

Bound morphemes that when affixed to a root or stem change the syntactic category and/or the meaning of the word are called derivational morphemes. For example, the addition of the suffix *-en* to an adjective turns it into a verb, as in *lighten*. The rule-governed combination of morphemes thus enables the formation of new words/meanings within a language (Aronoff, 1976; Greenberg, 1966; Sapir, 1921). When new words are formed they are still subject to regular inflectional rules; bound morphemes that obey rules for marking

grammatical properties such as tense, number, gender, case, etc., are called inflectional morphemes. They do not add new lexical meaning but have a strictly grammatical function, following the rules for sentence formation in the language.

Feldman and Andjelković (1992) characterized derivational and inflectional processes as differing along two main dimensions—(i) the productivity of rules applied, and (ii) the semantic distance between the root and inflected vs. derived forms. Derivational processes allow for more productivity leading to the generation of new meanings. Inflection is typically used to denote relative differences, such as changes in number, tense, and aspect (e.g., *walks*, *walked*, *walking*), whereas derivation combines a root with one or more morphemes to produce a distinct concept that is typically semantically related to the original concept (e.g., *walker*, *walkable*, from *walk*).

Languages vary widely in their degree and use of inflectional and derivational morphology. Languages such as Kannada and Turkish, for example, allow users to generate novel morphological forms in everyday speech. In contrast, languages like English and Swedish are considered morphologically limited, due to the relative inflexibility of rules for combining morphemes, as well as syntactic constraints on word order and function.

Another important respect in which languages differ is in the means by which morphologically complex words are formed. On this dimension, the morphological structure of languages may be classified as *concatenative* or *non-concatenative*. In the former category of languages, morphological formation involves *affixation*, that is, the linear combination of morphemes, as is the case in English, where suffixes and or prefixes are attached to a stem, yielding new words (e.g., *re+doubt+able*, *dis+enchant+ment*). Languages with non-concatenative morphology, on the other hand, form new words by a process of *infixation*, whereby morphemes are combined in a non-linear manner. For example, the affix *-um* combines with the morpheme *sulat* (meaning *to write*) to yield *sumulat* (*one who wrote*) in Tagalog (McCarthy & Prince, cf. Aronoff & Fudemann, 2005).

Research in psycholinguistics related to morphology initially sought evidence for a distinct, morphological level of representation in the mental lexicon (Taft & Forster, 1975). The question of interest in many early studies was whether morphologically complex words are represented intact or stripped of their affixes. More recently, attention has shifted to how morphologically complex words are processed in real time. The question of interest here is whether morphological structure facilitates word recognition, independently of other influences such as those of word form (phonology and/or orthography) and meaning

(Andrews, 1986; Fowler, Napps & Feldman, 1985; Marslen-Wilson, Tyler, Waksler & Older, 1994; Stanners, Neiser, Hernon & Hall, 1979).

Investigations of the influence of morphology on word recognition have employed priming as the primary technique. Priming is said to occur when participants' responses on a lexical decision task or word naming are facilitated when the target words are preceded by words that are morphologically related. Thus, for example, the morphologically related prime, *worker*, as compared to the unrelated prime, *singer*, speeds up recognition of the target word *work*. However, morphological relationships in languages like English are generally conflated with phonological (sound), orthographic (spelling) and semantic (meaning) overlap between words, as in the above example. Consequently, researchers have recognized the need for demonstrating morphological effects in the absence of significant form and meaning overlap.

Early studies succeeded in demonstrating some degree of dissociation between morphological and form overlap. A study by Fowler, Napps and Feldman (1985) used a long-lag, visual priming task, in which primes and targets were separated by several intervening items. Fowler et al. reported that target recognition was equally facilitated by primes with highly overlapping phonology (e.g., *healer* – *heal*) as by those with dissimilar phonology (e.g., *health* – *heal*). Marslen-Wilson and

Zhou (1999) reported similar results using a cross-modal priming task, with auditory primes and visual targets.

Feldman and Moskovljević (1987) additionally provided evidence that morphological priming may transcend orthographic overlap entirely. In their study, Serbo-Croatian readers' recognition of targets presented in Roman script was equally facilitated by identity primes presented in Roman (RUPI – RUPI) and in Cyrillic script (PYIII – RUPI); both scripts are typically used to represent Serbo-Croatian.

Initial evidence that morphology may be dissociable from semantics was presented by Feldman and Stotko (cf. Feldman, 2000), who found similar amounts of morphological priming among semantically close (*creation* – *create*) and semantically distant word pairs (*creature* – *create*). However, in an influential study, Marslen-Wilson et al. (1994) showed that morphological effects depend on *morphological transparency*, that is, the existence of a perceptible, meaningful relationship between prime and target.

Using a cross-modal priming task with auditory primes and visual targets, Marslen-Wilson et al (1994) manipulated the degree of form as well as meaning overlap between primes and targets and found priming effects of similar magnitude for words with different degrees of form overlap, such as *confessor* – *confess* and *elusive* – *elude*. Critically, Marslen-Wilson et al. reported no priming for *morphologically opaque*

word-pairs. That is, their results indicated no priming among words whose common etymology had been obscured over time, for instance, *department* – *depart* and *apartment* – *apart*. Similar effects of morphological transparency have been reported in French for visually primed lexical decision (Giraudo & Grainger, 2001).

These findings led researchers to formulate models of morphological representation in which only meaningfully related morphological relatives were organized into morphological families or clusters (Burani & Caramazza, 1987; Caramazza, Laudanna & Romani, 1988; Laudanna & Burani, 1995; Marslen-Wilson et al., 1994; Schreuder & Baayen, 1995). To illustrate, such a model would represent

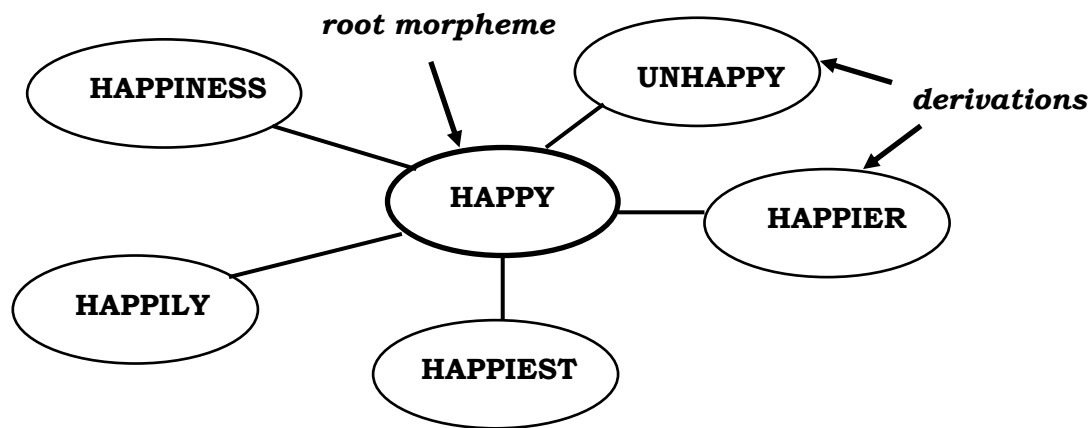


Figure 1 – Morphological representation in the satellite entries approach (e.g., Caramazza, Laudanna & Romani, 1988). The root morpheme forms the central node, and derivations are represented as auxiliary nodes.

depart, *departed* and *departure* but not *department* as part of a single family. Further, these models postulated that morphologically transparent, complex words are accessed by decomposition into their constituents; thus, the processing of *departure* involves decomposition into its constituent morphemes (*depart+ure*), but *department* is represented and accessed as a single, non-decomposed unit. (Refer to Figure 1 for an illustration of this view.)

Further support for the view that semantic analysis is an inherent part of morphological processing is provided by studies of morphological compounds (Sandra, 1990; Shoolman & Andrews, 2003; Zwitserlood, 1994), as well as by neuropsychological evidence (Hamilton & Coslett, 2002). Sandra (1990) compared recognition of morphologically transparent vs. morphologically opaque compound words in Dutch which were primed by semantic associates of their constituent morphemes. Transparent compounds reflect the original meanings of their constituent morphemes (analogous to *milk – cheesecake*), whereas opaque compounds do not (*pan – crackpot*). Results revealed that priming by semantic associates of morphemes was limited to morphologically transparent compound words and did not occur in opaque compounds (see Libben, Gibson, Yoon, & Sandra, 2002, for a more extensive investigation of the role of semantic transparency in compound word priming.)

Neuropsychological evidence from patients with different kinds of dyslexia also illuminates this issue. Phonological dyslexia is characterized by an impaired ability to convert spelling to sound, with poor performance in reading even simple pseudowords (e.g., *faper*, *hoating*), despite unimpaired reading of irregular but familiar words (e.g., *women*, *yacht*). Hamilton and Coslett reasoned that phonological dyslexics should make more mistakes while reading morphologically transparent words (e.g., *exactly*), as these are thought to require decomposition, than in reading opaque derivations (e.g., *hardly*), which are presumably stored and accessed as whole words. Their results confirmed this hypothesis, thus indicating that morphological processing is associated with semantic relatedness.

Reconsidering the Role of Form and Meaning: A Two-Stage Approach

During the past decade, however, additional evidence has come to light which suggests that morphological priming is neither independent of form overlap, nor is it constrained entirely by meaning overlap. Rather, the time-course of morphological priming determines the relative importance of either factor in observed priming effects.

Two advancements in priming technique were primarily responsible for this breakthrough—first, improvements in experimental software enabled researchers to manipulate Stimulus Onset Asynchrony

(SOA), that is, the interval between prime and target exposure, on the order of milliseconds. Secondly, the development of the masked priming technique (Forster & Davis, 1984) allowed researchers to use a forward and/or a backward mask consisting of letters or other symbols (e.g., &&&&&) to minimize or completely eliminate participants' conscious awareness of the prime and, thereby, to study the automatic rather than strategic influence of the prime on target processing. By using very short prime-target SOA and masking the prime researchers were able to assess the impact of different types of prime-target overlap in the very early stages of visual word recognition.

Feldman and Soltano (1999) used masked priming to compare morphological priming among transparent (*casually* – *casualness*) and opaque word-pairs (*casualty* – *casualness*) at short and long SOAs of 66ms and 300ms, respectively. They found that both types of morphological pairs induced priming at the short SOA, but priming among opaque relatives dissipated by the long SOA of 300ms. Similar findings have subsequently been reported in Dutch (Diependaele, Sandra & Grainger, 2005), French (Longtin, Seguí & Hallé, 2003) and Russian (Kazanina, Dukova-Zheleva, Geber, Kharmalov, & Tonciulescu, 2008).

Masked priming studies in French (Longtin et al., 2003) and English (McCormick, Rastle & Davis, 2008; Rastle, Davis, Marslen-

Wilson & Tyler, 2000; Rastle, Davis & New, 2004) additionally revealed that at short SOAs of less than 50ms priming among morphologically opaque pairs such as *vignette* – *vigne* (*picture* – *vine*) and *brother* – *broth* was superior to priming among words sharing only form overlap, such as *abricot* – *abri* (French: *apricot* – *shelter*) and *brothel* – *broth*. The crucial difference between morphologically opaque and form-overlapping primes in the above studies was that the former were fully morphologically decomposable, that is, comprised of legal morphemes (e.g., *broth* + *-er*, in the case of *brother*), whereas form primes were not morphologically decomposable (*-el* in *brothel* is not a legal affix).

Reviewing the findings, Rastle and Davis (2008) proposed that morphological processing in languages such as English and French proceeds in two distinct stages, a preliminary stage consisting of *morpho-orthographic decomposition* and a later stage involving *morpho-semantic analysis*. During morpho-orthographic decomposition, the structure or surface form of a word is broken down into its constituent morphemes, and in the subsequent morpho-semantic stage, the meaning of the constituents is verified against the meaning of the word as a whole. In Rastle and Davis's view (2008), morphological priming in the early stages of word recognition is sensitive to morpho-orthographic similarity, that is, to the appearance of a morphological relationship, whereas in the later stages priming occurs only for actually related, or

morphologically transparent, words. A similar two-stage theory of morphological processing was postulated by Diependaele et al. (2005). However, they proposed a race between the two systems, with an inherent advantage for the morpho-semantic system.

Rastle and Davis made four claims with respect to morphological processing. First, noting that the majority of studies (17 of 20 experiments) that reported morpho-orthographic priming used SOA settings shorter than 50ms, they claimed that *morpho-orthographic decomposition arises early and is an obligatory stage preceding semantic analysis*. Secondly, they argued that its early emergence as well as its occurrence under masked priming conditions suggests that *morpho-orthographic analysis is initiated unconsciously or subliminally*.

A third claim proposed by Rastle and Davis (2008) is the *pre-lexical origin of morpho-orthographic decomposition*, despite its sensitivity to morphological structure and grammatical constraints. To support this claim, Rastle and Davis cited the findings of Longtin and Meunier (2005; Meunier & Longtin, 2007), who recorded morphologically opaque priming by pseudoword primes in French. In their experiments, pseudowords comprising legal morpheme combinations (e.g., *rapidifier*) successfully primed real words (*rapide*, i.e., *fast*), but morphologically illegal pseudoword primes (e.g., *rapiduit*) did not lead to priming. Finally, Rastle and Davis outlined a fourth characteristic, that is, *the resilience*

of morpho-orthographic decomposition to minor variations in surface form, as evident from McCormick et al.'s (2008) finding that morphologically opaque primes which differed from the target in both phonology and orthography (e.g., *allegory* – *allege*, *fetish* – *fete*) nevertheless led to priming.

Morphological Processing as a Function of Morphological Structure

In their review, Rastle and Davis (2008) drew attention to an important constraint on the generalizability of their model, namely, that a two-stage model of morphological processing may be applicable only to Indo-European languages with a concatenative morphological structure (pp. 12-14), such as English and French. This observation was based on the demonstration by previous researchers of a contrast in morphological priming in languages like English and French, on the one hand, and that in Hebrew and Arabic on the other.

In contrast to the findings in English, French and other Indo-European languages, studies of Semitic languages such as Hebrew and Arabic have revealed a markedly different pattern of morphological priming. An early study by Bentin and Feldman (1990) found that, in Hebrew, priming was robust among morphologically opaque words even at later stages of word recognition. The authors found that whereas purely semantic priming (by analogy in English: *harbor* – *port*) dissipated

at intervals longer than a few seconds between prime and target, both transparent (*porter* – *port*) and opaque morphological primes (*portly* – *port*) continued to facilitate target recognition at long lags of as many as 13 intervening trials between the two items.

More recently, Frost and colleagues (Deutsch, Frost & Forster, 1998; Frost, Deutsch & Forster, 2000; Frost, Deutsch, Gilboa, Tannenbaum & Marslen-Wilson, 2000; Frost, Forster & Deutsch, 1997; Frost, Kugler, Deutsch & Forster, 2005) have demonstrated that, in Hebrew, morphological priming among opaque relatives arises early and generalizes across word-classes and degrees of morphological productivity. For example, Deutsch et al. (1998) recorded equivalent priming among transparent word-pairs like /haklata/ – /taklit/ (*recording* – *record*) and opaque pairs such as /klita/ – /taklit/¹ (*absorption* – *record*); all words are derived from the root *KLT*, which denotes the concept of ‘taking in’. Similarly, Boudelaa and Marslen-Wilson (2001, 2004) concluded that, in Arabic, priming among morphologically opaque prime-target pairs (e.g., /ittiaahun/¹ – /waaaha/, *destination* – *confront*) was equal to that in morphologically transparent pairs (e.g., /ittifaqun/ – /waafaqa/, *agreement* – *agree*).

Frost et al. (1997) proposed that the above pattern is attributable

¹ Phonological transcription used for Hebrew words adopted from Frost et al. (1997), and for Arabic from Boudelaa and Marslen-Wilson (2005).

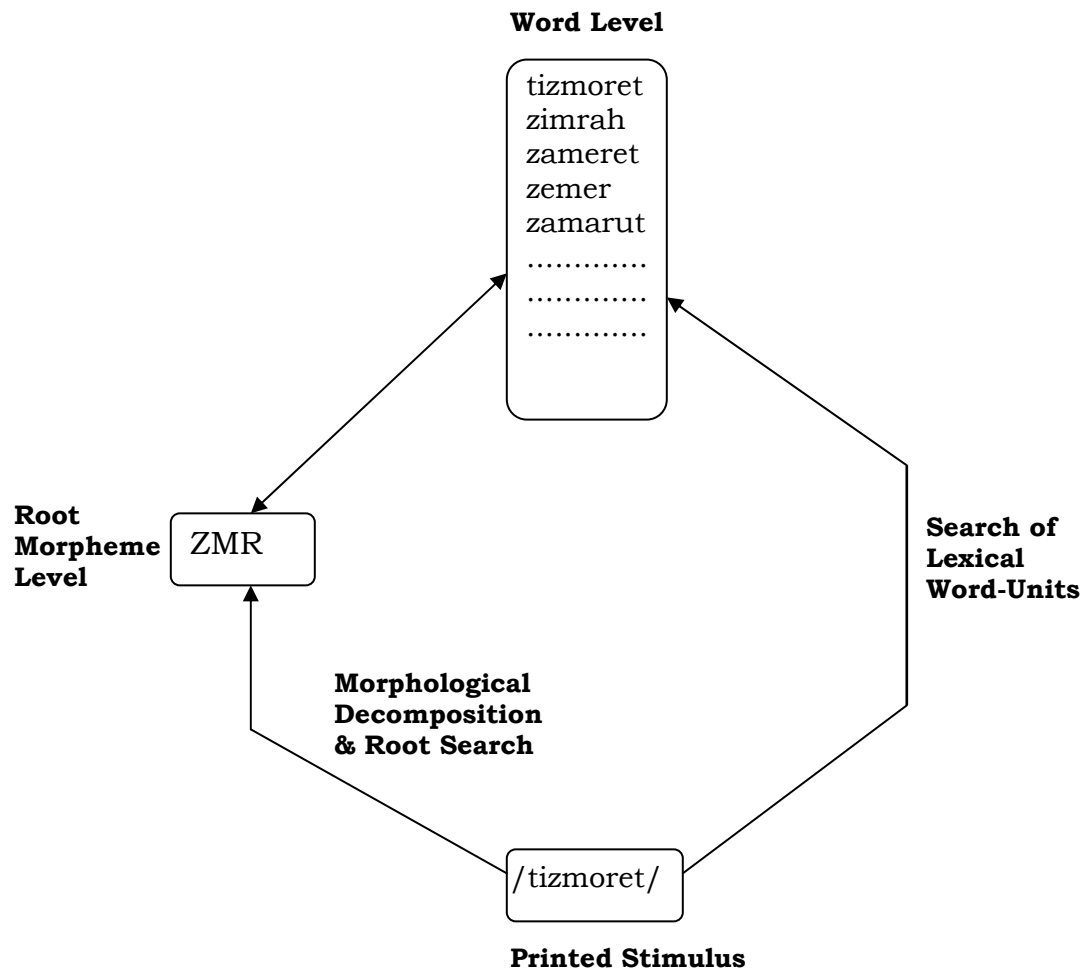


Figure 2 – *Morphological representation and processing in Frost et al.'s (1997) model. All words formed from a common root morpheme are linked to the root, facilitating mutual activation among morphologically transparent as well as opaque relatives. [Figure adapted from Frost et al. (1997).]*

to the non-concatenative morphological structure of Hebrew and Arabic.

As described in the introduction, concatenative morphologies like

English use affixation to form new words, whereas, non-concatenative

languages form words by a process variously termed *infixation*, *intertwining* and *interleaving*. In Arabic and Hebrew morphologies, words are formed by the intertwining of root morphemes, which typically consist of two to three consonants, with word patterns, which include one or more vowels and sometimes consonants, to yield words. For instance, the Hebrew root *ZMR*, denoting concepts related to singing, may be combined with different word patterns such as *_ A _ A _* and *T I _ _ O _ E T*, denoting masculine and feminine nouns respectively, to yield words like */zamar/* (*male singer*) and */tizmoret/* (*orchestra*).

The non-concatenative nature of morphology in these languages, according to Frost et al. (1997), makes root morphemes especially salient in Hebrew and Arabic. Accordingly, root morphemes are represented at a distinct level of the mental lexicon in Frost et al.'s model. Further, the model proposes that all words derived from a common root are connected to the representation of the root morpheme, irrespective of their morphological transparency (see Figure 2 for a schematic illustration).

Morphological Processing as a Function of Morphological Productivity

The models and theories described in the foregoing sections are based on the common assumption that representation and processing of morphological information are determined by the morphological

structure or typology of a specific language or group of languages (Caramazza et al., 1988; Diependaele et al., 2005; Frost et al., 1997; Giraudo & Grainger, 2001; Marslen-Wilson et al., 1994; Rastle & Davis, 2008; Schreuder & Baayen, 1995).

An alternative view taken by some researchers proposes that differences in morphological processing between languages are attributable to variations in morphological productivity, that is, to the richness and consistency of relationships between morphemic units within a language (Plaut & Gonnerman, 2000; Rueckl & Raveh, 1999). This approach is grounded in the idea that morphology is an emergent phenomenon, in other words, that systematic regularities in mapping between units representing form and meaning within the mental lexicon strengthen the connections between them, leading to the emergence of phenomena such as morphological priming (Gonnerman, 1999; Plaut & Gonnerman, 2000; Rueckl & Aicher, 2008; Rueckl & Gantalucci, 2005; Rueckl, Mikolinski, Raveh, Miner & Mars, 1997; Rueckl & Raveh, 1999; Seidenberg & Gonnerman, 2000).

In this view, languages with richer and more consistent mapping between form and meaning level units should exhibit more robust morphological priming, while those with relatively sparse and inconsistent relationships between form and meaning should support morphological priming only conditionally. Following this reasoning,

Plaut and Gonnerman (2000, p. 463) described English morphology as being “relatively impoverished” in comparison with Hebrew.

In Hebrew, words sharing a root morpheme have a high probability of being meaningfully related—thus, most if not all words sharing the root *ZMR* are related to the concept of *song* or *music*. Likewise, words sharing a word pattern invariably signify a particular grammatical category; for example, the pattern _ A _ A _ signifies a *male agent*. By contrast, English exhibits great variation in the correspondence between morphological segments and meaning—compare *corn*, *corner*, *cornet* and *cornice*, or the *-er* in *baker*, *bigger* and *brother*. For a detailed exposition on the gradations in morpheme status and morphological structure, see Aronoff (1976) and Bybee (1985).

Further, although morphological families in English range in size from 1 to 200 (Moscoso del Prado Martin, Deutsch, Frost, Schreuder, de Jong & Baayen, 2005), a large proportion of English words have few or no morphological neighbors in comparison with Hebrew, in which a majority of words have multiple morphological neighbors, despite the narrower range in morphological family size (1 – 30).

Thus, Plaut and Gonnerman (2000) argued that the difference in the morphological productivity of English and Hebrew was responsible for the divergent patterns of morphological priming in the two languages. Specifically, they claimed that the sparseness and inconsistency of

relations among orthographic (form) and semantic (meaning) units in English discourages priming among morphologically opaque words such as *corner* – *corn*, whereas the relative richness and consistency of such relationships in Hebrew supports robust priming among morphologically opaque words solely on the basis of apparent morphological relatedness.

To test this claim, Plaut and Gonnerman (2000) trained their connectionist model of word recognition using two sets of stimuli: one set mimicked the *impoverished* morphology of English, while the other resembled Hebrew in morphological productivity. When tested later, the English-like set exhibited priming only among morphologically transparent stimuli, whereas the second set of (Hebrew-like) stimuli exhibited priming among morphologically opaque units. From this, the authors concluded that morphologically opaque priming in Hebrew is a natural outcome of its morphological productivity.

Morphological Structure vs. Productivity: Unresolved Questions

Although the approaches based on morphological structure vs. productivity offer very different solutions to the problem of morphological representation and processing, neither approach provides a comprehensive explanation of the extant evidence. By definition, models based on morphological structure should generalize across typologically comparable languages. Thus, morpho-orthographic

decomposition as described by the two-stage models (Diependaele et al., 2005; Rastle & Davis, 2008) should similarly characterize morphological processing in languages with concatenative morphology.

However, Diependaele et al.'s (2005) results revealed a significant difference in morphological priming patterns between Dutch and French. Using Longtin et al.'s (2003) stimuli and an SOA of 67ms, Diependaele et al. (2005) found strong evidence for morpho-orthographic priming among visually presented French words. In contrast, Dutch targets (e.g., *ton*, meaning *barrel*) showed no facilitation by morphologically opaque primes (e.g., *toneel* meaning *theater*) when compared with unrelated controls (e.g., *arbeid* meaning *work*); a weak facilitative effect of morpho-orthographic primes emerged only in comparison with form-overlapping primes (e.g., *tonijn*, meaning *tuna*).

Likewise, Frost et al.'s (1997, 2005) model of non-concatenative morphology (see pp. 11-13) fails to account for an important phenomenon, namely, priming based on form overlap. Frost et al. (2005) contended that since connections among words in non-concatenative languages like Arabic and Hebrew are based exclusively on shared morphemes, similarity in the surface forms of words should have no effect on word recognition in either language. Indeed, Frost et al.'s (2005) study used an SOA of 43ms and found no form priming either in Hebrew (e.g., /sidur/ – /sipur/, *arrangement* – *story*) or in Arabic (e.g.,

/kamaal/ – /Zamaal/, *perfection – beauty*). In contrast, Boudelaa and Marslen-Wilson (2005) used a prime-target SOA of 80ms, and found consistent priming among Arabic nouns as well as verbs that were similar only in form e.g., /taʔmiimun/ – /taammun/, *nationalization – complete*). An early study by Bentin (1989) similarly observed form priming in Hebrew at long intervals (3s and longer) between prime and target exposure.

An additional prediction arising out of Frost et al.'s (1997, 2005) model is that morphologically related words in Arabic and Hebrew should show equivalent priming across varying degrees of morphological transparency. That is, priming among morphologically opaque words should be comparable to that among morphologically transparent words in non-concatenative languages. Diverging from this prediction, Frost et al.'s (2000b, Exp. 2) results revealed significantly greater priming in Hebrew among transparent as opposed to opaque morphological relatives. For example, the target word /hadraxa/ (*guidance*) showed greater facilitation when preceded by a transparently related prime such as /madrix/ (*guide*) than by an opaque prime like /drixut/ (*alertness*).

Similarly, the morphological productivity approach of Plaut and Gonnerman (2000) does not explain priming based on morpho-orthographic similarity in languages like English and French. According to Plaut and Gonnerman, English has fewer and relatively inconsistent

morphological relationships, and should therefore exhibit little or no priming among morphologically opaque pairs. Yet, the evidence shows that, in the initial stages of word recognition, English supports equivalent priming by morphologically opaque and transparent primes, both being superior to form-overlapping primes.

Reconciling the Differences: The Role of Orthographic Depth

The current study proposes that explanations of morphological processing incorporate the factor of orthographic depth in order to better account for the findings observed across languages. In a seminal paper, Frost, Katz and Bentin (1987) defined ‘orthographic depth’ as the degree of phonological transparency of a writing system, that is, the extent to which the spoken units of a language (e.g., phonemes, syllables) are directly represented by the written units of that language.

Researchers and theorists widely acknowledge that retrieving meaning from print is influenced by the orthographic depth of the writing system, and that skilled readers have two routes available for word identification. The indirect access or *phonological assembly* route involves forming a phonological representation of a word from individual graphemes or characters prior to accessing word meaning. The second route is theorized to develop with cumulative reading experience and proficiency; in this *direct* or *lexical* route, the visual form of the word is

used to directly access meaning, with no intermediary stage of phonological assembly.

Evidence indicates that readers of *deep* orthographies such as Arabic, and Hebrew make greater use of the direct route (Bentin, 1989; Bentin, Bargai & Katz, 1984; Bentin & Frost, 1987; Bentin & Ibrahim, 1996; Frost et al., 1987; Roman & Pavard, 1987). On the other hand, in *shallow* orthographies like Serbo-Croatian and Italian, readers have been found to rely more extensively on phonological recoding prior to lexical access (Feldman & Turvey, 1983; Frost et al., 1987; Lukatela & Turvey, 1987; Lupker, Brown & Colombo, 1997).

Standard Arabic and Hebrew are considered to be orthographically deep scripts due to their omission of the majority of vocalic information. The omission of vowel markers or diacritics in these scripts makes it relatively difficult to recover the phonological form of a word by systematic conversion of spelling into sound (phonological assembly). By contrast, Indo-European languages like English and French are relatively orthographically shallow, as their scripts require representation of vowels in spelling. Nevertheless, there are significant differences in orthographic depth within the Indo-European group—languages such as Italian and Spanish are classified as orthographically shallow, while French is considered a deeper orthography and English even more so.

Thus, orthographic depth might underlie the differences observed among previous studies in morphological priming. For instance, Diependaele et al.'s (2005) finding that masked morpho-orthographic primes failed to yield priming in Dutch at a 67ms SOA, but that French stimuli showed strong priming under identical conditions may be ascribed to the relative phonological transparency of Dutch as compared to that of French (Van den Bosch, Content, Daelemans & de Gelder, 1994). The orthographic depth explanation predicts that morpho-orthographic effects should arise (and possibly dissipate) earlier in Dutch, and should therefore be observable at a shorter prime-target SOA.

In a like manner, the greater orthographic depth of Arabic and Hebrew may account for the observation by Boudelaa and Marslen-Wilson (2005) as well as Bentin (1989) that form-based priming arises relatively late in these scripts. Due to the omission of most vowels from these Semitic scripts in texts directed at proficient readers, it may require longer to compute a full internal representation of words that includes missing orthographic information. Consequently, priming based on form level similarity may be expected to arise later in Arabic and Hebrew as compared to English. Further, the typical omission of vowels in Arabic and Hebrew orthography may discourage reliance on vocalic information in distinguishing word meanings, thus leading to

relatively small differences in priming between morphologically transparent (*farmer* – *farm*) and opaque pairs (*corner* – *corn*) that share the critical root consonants.

The phenomenon of morpho-orthographic priming in languages classified as relatively morphologically unproductive by Plaut and Gonnerman (2000) may also be explained by taking orthographic depth into consideration. It is plausible that languages such as English, which are characterized by morphological inconsistency, have stronger top-down inhibitory connections from meaning units to lower level form units than do morphologically consistent languages like Hebrew. In this view, the initial activation of incorrect meaning by the morphological structure of the prime (as in *broth+er*) should lead to morpho-orthographic priming in the inconsistent language, which should nonetheless dissipate as soon as top-down inhibitory processes are activated.

DOES ORTHOGRAPHIC DEPTH MEDIATE MORPHOLOGICAL PROCESSING? THE CASE OF HINDI AND URDU

An ideal test of whether orthographic depth indeed mediates morphological processing over and above the influence of previously explored factors such as morphological structure and productivity would be to vary orthographic depth while keeping morphological relationships constant. The languages Hindi and Urdu allow exactly this contrast.

Brief Historical Overview of Hindi and Urdu

Although Hindi and Urdu have taken on distinct sociocultural identities in modern-day India, scholars are agreed that these members of the Indo-Aryan branch of the Indo-European family of languages have a common historical origin (Ahmad, 2008; Cardona & Jain, 2003; Kachru, 2008; Masica, 1991). The evolution of Hindi/Urdu spanned the eleventh to the nineteenth centuries, during the period of Islamic conquest and rule over a substantial part of what is now India. Hindi/Urdu took shape as a composite mix of the regional dialects current in and around the capital (Delhi), while being substantially influenced by Persian, the court language of the Mughal (Islamic) rulers, as well as by older languages and dialects such as Prakrit and Apabhramsh.

The terms *Hindvi* (or *Hindavi*) and *Urdu*, among others, were used to refer to the newly evolving language—the term *Hindvi* was used to designate the language of the people of Hind (the region around the Indus or Sindhu river), while the term *Urdu* originated from the Turkish word for *army encampment*. These terms continued to be used to describe the language until well into the seventeenth century, by which time the name *Hindustani* (meaning *of India*) gained currency. The adoption of Urdu/Hindustani as the official court language by the British administration in India fueled sociopolitical dynamics, leading to the cleavage of *Modern Standard Hindi* (henceforth termed *Hindi*) from the parent Urdu/Hindustani language. Efforts to sustain the rift between Hindi and Urdu have adopted classical Sanskrit as the source for expanding Hindi vocabulary, thereby distancing it increasingly from Urdu; there has been a corresponding tendency to draw increasingly on Persian and Arabic to enrich Urdu vocabulary.

Orthography vs. Morphology in Hindi/Urdu

Notwithstanding the social and political dynamics described above, the dominant regional language spoken across a large swathe of present-day northern India is a form of Hindi/Urdu that is mutually intelligible to communities in northern India that claim either Hindi or Urdu as their native language. Other users of Hindi and Urdu, as for

example urban, Hindi-speaking populations in southern, northeastern or western India as well as Urdu-speakers in Pakistan are also intelligible to northern Indian users, although slightly less so. By implication, Hindi and Urdu are nearly identical in morphophonology, and share a common grammar. While the formal registers of these languages evince Sanskrit and Perso-Arabic influences respectively, the languages have a core shared vocabulary.

The boy was walking :	/la□kā	□al	rahā	thā/
	<i>boy</i>	<i>walk</i>	<i>be</i>	<i>was</i>
The boys were walking:	/la□ke	□al	rahe	the/
	<i>boys</i>	<i>walk</i>	<i>be</i>	<i>were</i>
The girl was walking :	/la□kī	□al		rahī
				thī/
	<i>girl</i>	<i>walk</i>	<i>be</i>	<i>was</i>
Make the boys walk :	/la□kō	ko	□alāo/	

Figure 3 – *Phonetic transcriptions of Hindi/Urdu sentences illustrating gender derivations ('boy' vs. 'girl'), as well as number ('boy' vs. 'boys') and case inflections (direct vs. oblique forms of 'boys') of a single noun, as also noun – verb agreement in Hindi/Urdu (the verb form of 'was' agrees with gender and number of the noun in each case).*

In marked contrast to English, morphology in Hindi/Urdu is not confined to the lexical level, but rather requires the agreement of morphological markers across grammatical categories to achieve morphological distinctions. This complexity led Masica (1991, p. 212) to remark that an account confined to descriptions of inflections and derived forms, in the style of traditional grammars, would “be fragmentary, and not give much of an idea of how these languages actually work”. Accordingly, the following brief description treats Hindi/Urdu morphology holistically.

The complex nature of Hindi/Urdu morphology is evidenced by the heterogeneity of processes involved in word formation—owing to the influence of local dialects, classical (Prakrit, Sanskrit), as well as foreign languages (Arabic, Persian), morphological formation in Hindi/Urdu includes analytic and synthetic as well as agglutinative elements. An added dimension of complexity stems from the contribution of lexical as well as syntactic elements to morphological expression in Hindi/Urdu. That is, concepts such as gender, number and case in these languages are indicated by agreement among the forms of several words, rather than by a single word. Finally, the morphological structure of Hindi/Urdu is mostly concatenative, but includes a non-concatenative element that is extensively employed in verb formation (Cardona & Jain, 2003; Kachru, 2006; Mathur, 2004; 2007; Singh & Agnihotri, 1997).

The high productivity of Hindi/Urdu was suggested earlier while drawing attention to the need for grammatical agreement in morphological expression. Thus, noun declension involves marking of gender and number, as well as marking of direct, oblique and vocative cases. For example, multiple words mark male (/la□kā/, /rahā/, /thā/) vs. female gender (/la□kī/, /rahī/, /thī/) in the sentences in Figure 3.

Similarly to nouns, adjectives in Hindi/Urdu are marked for gender, number and case. Pronouns are marked for case only. Verbs are marked for mood, tense, and aspect in addition to having specific inflections for gender and number agreement. Adverbs are morphologically invariable, as are conjunctions, particles and interjections. Hindi/Urdu uses postpositions in preference to prepositions, and these are also marked for gender, number and case. Thus, the combined effect of noun declension, verb marking, and the marking of adjectives and postpositions to agree with nouns renders Hindi/Urdu morphology very rich, but also highly consistent.

In contrast to the shared morphophonological and grammatical identity of Hindi and Urdu, the two languages are written in very different orthographies. Hindi makes use of the orthographically shallow, alphasyllabic Devanagari script, originally used to write down Sanskrit, whereas Urdu employs an orthographically deep, that is, phonologically opaque, Perso-Arabic script that omits most vowels from standard text,

following the convention of Arabic and Persian. (For a more detailed description of Hindi orthography, refer to Vaid & Gupta, 2002; for details on Urdu, see Ahmad, 2008.) Thus, a word in Hindi/Urdu bearing a single semantic identity and morphophonological structure is represented in two orthographically distinct ways (see example in Figure 4). A full description of Hindi and Urdu alphabets, along with IPA (2005) phonetic transcriptions as well as those used in the current study is provided in Appendix A.

/pānī/ (water): पानी (Hindi) پانی (Urdu)

Figure 4 – *Orthographically distinct representation of a single word in Hindi (Devanagari script) and Urdu (Perso-Arabic script).*

Orthographic Depth and Word Recognition in Hindi vs. Urdu

Previous research by Vaid and colleagues has yielded divergent patterns in lexical processing strategies between Hindi and Urdu, similar to differences documented earlier between other orthographically shallow and deep scripts. In Hindi, word naming as well as lexical decisions were significantly affected by word length (number of syllables), whereas the effect of frequency was significant only for words of one and

two syllables; further, visual stimulus quality did not interact with word frequency (Vaid, Rao & Chen, 2008a). These results suggest that, in Hindi, readers rely on a phonological assembly strategy. By contrast, a robust effect of word frequency was found in Urdu, whereas word length exercised a significant influence only on low frequency words (Vaid, Rao, Chen, Kar & Sharma, 2008b), suggesting that the direct access route is preferred for word recognition in Urdu.

The Present Study

As described at the outset, the first aim of the present study was to examine whether the difference in orthographic depth between Hindi and Urdu mediates morphological priming. Specifically, the hypothesis was tested that early-arising, masked morphological priming, or priming based on morpho-orthographic decomposition is supported only in orthographies that allow easy recovery of phonological information. Thus, it was expected that the orthographically shallow Hindi script would behave similarly to English and French by exhibiting superior morphological priming for very briefly presented (less than 50ms), forward masked primes. In contrast, the greater orthographic depth of Urdu was expected to preclude morpho-orthographic decomposition; Urdu was expected to exhibit morphological priming only when primes were available for conscious, morpho-semantic processing.

The above predictions were tested in three experiments in which the effect of morphological primes on Hindi and Urdu word recognition was measured with reference to recognition of words preceded by unrelated primes (baseline or control condition) or by form-overlapping primes. Note that the inclusion of a form priming condition allowed the assessment of morphological priming in two ways—facilitation by morphological primes in the absence of an effect of form-overlapping primes provided one index of morphological priming, and superior performance (accuracy and/or speed) on morphologically primed words relative to those cued by form primes provided a second index of morphological priming.

Due to the extreme orthographic shallowness of Hindi it is difficult, if not impossible, to find morphologically opaque words in Hindi/Urdu (analogous to *department* – *depart*). Thus, the experiments reported here compared priming among words whose morphological relationship was transparent. As outlined earlier, Rastle and Davis (2008) concluded from the literature that morpho-orthographic decomposition is characterized by early onset and unconscious origin. Thus, Experiments 1 to 3 used the presence vs. absence of a forward pattern mask, as well as a brief prime-target SOA of 48ms to test for the morpho-orthographic nature of observed priming effects.

EXPERIMENT 1: TIME COURSE OF MORPHOLOGICAL VS. FORM PRIMING IN NAMING HINDI VS. URDU WORDS

In this experiment, speeded naming of Hindi and Urdu was examined as a function of prior masked presentation of morphological and form primes at three different SOAs: 48ms (short), 80ms (medium) and 240ms (long). Targets were Hindi/Urdu words of one syllable (e.g., /bak/, *empty talk*), paired with two-syllable primes of three types—morphologically-related (e.g., /bakvās/, *nonsense*), form-overlapping (e.g., /bakrī/, *goat*) and unrelated or control primes (e.g., /jhop□ī/, *hut*), analogously to *trick* primed by *trickster*, *trickle* and *lemon*.

The short SOA was chosen to resemble previous studies which observed consistent morpho-orthographic priming at SOAs shorter than 50ms in English (Rastle et al., 2000, 2004) and French (Longtin et al., 2003). The medium SOA was selected to test the explanation suggested in a previous section (see p. 21) that form priming arises relatively late in orthographically deep scripts due to the necessity of comparing whole-word orthographic representations rather than smaller, sub-lexical units. The similarity of Urdu to Arabic script, from which it is descended, led to the prediction that Urdu would exhibit form-based priming at the 80ms SOA in a similar pattern to that reported for Arabic by Boudelaa and Marslen-Wilson (2005).

The choice of long SOA was based on the widely documented superiority of morphological over form priming at SOAs greater than 220ms. Studies across English (Feldman & Soltano, 1999; McCormick et al., 2008; Rastle et al., 2000, 2004), German (Drews & Zwitterlood, 1995) and Serbo-Croatian (Feldman & Andjelković, 1992; Feldman & Moskovljević, 1987) have revealed morpho-semantic priming, that is, robust priming among transparent morphological relatives at long SOAs. In the current experiment, therefore, it was expected that both Hindi and Urdu would exhibit superior morphological over form priming at the long SOA of 240ms.

Method

Participants. Ninety-two proficient biscriptal readers of Hindi and Urdu were recruited from a university in Allahabad, in northern India. The sample included 73 males and 19 females, and ranged from 18 to 39 years in age, with a mean age of 24. Participants used Hindi and Urdu on a daily basis. Hindi was the medium of instruction of most participants, and most had learned Urdu in elementary school and beyond. Further, all participants in the present study had studied Urdu at university level. Based on a 7-point scale, participants rated themselves as highly proficient in reading in Hindi (Mean = 6.6, $SD = 0.8$)

and in Urdu (Mean = 6.6, $SD = 0.9$). Participants were paid per hour of involvement in the study.

Design and Materials. The design of the experiment was a 2 (Script: Hindi, Urdu) by 3 (Prime Type: morphological, form, control) by 3 (SOA: 48ms, 80ms, 240ms) mixed factorial, with repeated measures on the first two factors. Twenty-seven participants were tested at the short SOA, 32 at the medium SOA, and 33 at the long SOA. Stimuli were 312 Urdu-Hindi words of medium frequency, including 78 targets and 234 primes. Targets were all monosyllabic words, while primes were bisyllabic. Subjective word frequency ratings (on a 7-point scale) were obtained from small groups of proficient readers (12 to 14 raters per word) as a manipulation check, revealing that in Hindi, targets were rated 4.6 ($SD = 1.2$) and primes 4.7 ($SD = 1.3$), whereas in Urdu, targets received an average rating of 5.3 ($SD = 1.0$) while primes were rated 5.2 ($SD = 1.2$)².

Each of the 78 targets was paired with three types of primes: morphologically and form related (termed *morphological*), related only in form (termed *form*) and unrelated (termed *control*); see Table 1 for an example. Due to the constraints in selecting stimuli, it was not possible

² Separate ANOVA of average frequency ratings in Hindi and Urdu revealed significant differences among prime types in both languages, and Tukey's HSD tests revealed that control primes received significantly higher frequency ratings compared to morphological and form primes in Hindi as well as Urdu. However, an inflated priming effect arising from inhibition of control targets by higher frequency primes was ruled out by comparing latencies to control targets paired with high vs. low frequency primes (prime grouping based on median split), which revealed **shorter** latencies to words paired with high frequency control primes in Hindi, and no difference in Urdu.

to control for word-class. Refer to Appendix A for a detailed description of stimuli. Bitmap images of individual words (white text on black background) were prepared from Hindi stimuli typed in Myhindigyan font, size 20, and Urdu stimuli in Nastaliq font, size 18. An additional set of 96 words was similarly compiled to serve as fillers, consisting of 48 single syllable targets paired with randomly chosen two-syllable words.

Procedure. Stimuli were presented using E-Prime experimental software (Psychological Software Tools Inc., 2003) in a speeded naming task. An initial fixation cursor (800ms) was followed by a forward mask presented for 500ms (a row of eight hash signs for Hindi words, and vertical lines for Urdu), which was replaced by the prime (48ms/ 80ms/ 240ms). In turn, the target replaced the prime and remained on screen until participants named the word aloud. Response latency from the onset of the target until participants' response, was logged in milliseconds using a voice-onset key (Psychological Software Tools Inc.), while accuracy was manually coded later based on digital recordings of experiment sessions (Sony® Digital Voice Recorder, ICD P-320). The inter-stimulus interval (ISI) was 1000 ms.

Participants were presented 39 experimental prime-target pairs each in Hindi and Urdu, in separate, counterbalanced blocks. Within each block, there were 13 pairs each from the morphological, form and

Table 1

Example of Prime-Target pair used in Experiments 1, 2 and 4.

	Target	Priming Conditions		
		Morphological	Form	Control
Hindi	बक	बकवास	बकरी	झोपड़ी
Urdu	بک	بکواس	بکری	جھوپڑی
Pronunciation	/bak/	/bakvās/	/bakrī/	/jhop□ī/
Meaning	<i>empty talk</i>	<i>nonsense</i>	<i>goat</i>	<i>hut</i>
Analogy	<i>TRICK</i>	<i>TRICKSTER</i>	<i>TRICKLE</i>	<i>LEMON</i>

control conditions, along with 24 filler pairs (that is, 63 pairs per block), with a rest pause after every 21 trials. Each target was paired with all three primes in both languages, creating twelve counterbalanced blocks (six per language), within which stimuli were further randomized, ensuring that no participant saw a word more than once.

Results

Participants' mean accuracy and reaction time (RT) per experimental condition were computed (see Table 2). Naming accuracy was uniformly high across Hindi (98.4%) and Urdu (95.2%). RT analyses

included only correct responses, and data were further trimmed by rejecting responses shorter than 250ms and longer than 1500ms; this removed an additional of 0.7% of Hindi and 1.5% of Urdu trials, respectively. Overall, participants were faster and more accurate in naming words presented in Hindi than in Urdu (RT mean difference = 106ms; accuracy mean difference = 3.3%, see Table 2).

Analyses of variance were then computed separately on RT and accuracy, that is, mean proportion of correct responses. The by-participant ANOVA treated Script (Hindi, Urdu) and Prime Type (morphological, form, control) as within-subjects variables and SOA (short, medium, long) as a between-subjects variable. (Refer to Appendix D, Table D-1 for complete ANOVA results.) The accuracy ANOVA yielded a main effect of Script both in the by-participants and by-items analyses, [$F_1(1, 89) = 39.09, p < .05, MSE = 0.004, \eta^2 = .31^3$; $F_2(1, 77) = 35.00, p < .05, MSE = 0.011, \eta^2 = .31$], reflecting greater accuracy in naming Hindi as compared to Urdu words. Neither Prime Type nor SOA affected accuracy, and there were no interactions.

RT data similarly revealed a significant effect of Script, with faster responses in Hindi than in Urdu (both by-participant and by-item $ps < .05$). A main effect of Prime Type also emerged ($ps < .05$), and the ANOVA by-items yielded a significant effect of SOA ($p_1 > .10$; $p_2 < .05$),

³ Estimates of effect size reported in this dissertation use the partial eta squared statistic.

which was qualified by a Script by SOA interaction [$F_1 < 1$; $F_2(2, 154) = 3.72$, $p < .05$, $MSE = 7136.53$, $\eta^2 = .05$]. Importantly, the RT data yielded a significant three-way interaction of Script, Prime Type and SOA in the ANOVA by-participants, with $F_1(4, 178) = 2.55$, $p < .05$, $MSE = 1084.19$, $\eta^2 = .05$; $F_2 < 2$. Refer to Figure 5 for an illustration of the

Table 2

Exp. 1: Participants' word naming latency (RT) and proportion accuracy to Hindi vs. Urdu targets preceded by morphologically-related (Morph), form-overlapping (Form) and unrelated (Control) primes (n = 92)

SOA (ms)	Prime		Hindi		Urdu	
	Type	N	Mean RT	Accuracy	Mean RT	Accuracy
Short	Morph	27	570 (15) ¹	0.99 (0.09)	680 (23)	0.94 (0.01)
	Form	27	584 (16)	0.97 (0.01)	676 (21)	0.95 (0.01)
	Control	27	609 (15)	0.99 (0.01)	693 (21)	0.95 (0.02)
Medium	Morph	32	560 (17)	0.99 (0.01)	679 (19)	0.95 (0.01)
	Form	32	567 (18)	0.99 (0.01)	683 (18)	0.96 (0.01)
	Control	32	591 (16)	0.98 (0.01)	716 (20)	0.96 (0.01)
Long	Morph	33	615 (17)	0.99 (0.01)	703 (21)	0.96 (0.01)
	Form	33	613 (16)	0.98 (0.01)	720 (22)	0.95 (0.01)
	Control	33	632 (15)	0.98 (0.01)	746 (27)	0.94 (0.01)

¹Standard error values italicized in parentheses

three-way interaction.

Script x Prime Type x SOA Interaction. In order to examine the higher order interaction, contrasts were computed using separate repeated measures ANOVA to assess the effect of Prime Type at each level of Script and SOA.

1. *Short SOA.* At the short SOA, Hindi exhibited priming relative to control in morphological [$F_1(1, 356) = 21.03, p < .05, MSE = 960.92, \eta^2 = .06; F_2(1, 924) = 12.31, p < .05, MSE = 4927.90, \eta^2 = .01$] as well as form related conditions [$F_1(1, 356) = 8.48, p < .05, MSE = 960.92, \eta^2 = .02; F_2(1, 924) = 4.80, p < .05, MSE = 4927.90, \eta^2 = .02$]. Further, the morphological condition proved marginally superior to the form condition in the by-participants analysis, $F_1(1, 356) = 2.80, p = .09, MSE = 960.92, \eta^2 = .01$. In contrast, Urdu exhibited no advantage for the morphological condition relative to the control (both the by-participant and by-item effects were not significant), but the by-participant means revealed an advantage for the form related condition relative to control, $F_1(1, 356) = 4.30, p < .05, MSE = 960.92, \eta^2 = .01$.

2. *Medium SOA.* At medium SOA, Hindi continued to show priming relative to control in morphological [$F_1(1, 356) = 16.13, p < .05, MSE = 960.92, \eta^2 = .04; F_2(1, 924) = 6.90, p < .05, MSE = 4927.90, \eta^2 = .03$] and form-overlap conditions [$F_1(1, 356) = 9.97, p < .05, MSE = 960.92, \eta^2 = .03; F_2(1, 924) = 4.67, p < .05, MSE = 4927.90, \eta^2 = .02$]. However,

there was no difference between morphological and form conditions (both by-participant and by-item analyses yielded $ps > .10$). Urdu revealed a clear advantage for the morphological over control condition at medium SOA [$F_1(1, 356) = 22.30, p < .05, MSE = 960.92, \eta^2 = .06; F_2(1, 924) = 10.55, p < .05, MSE = 4927.90, \eta^2 = .04$] and also an advantage

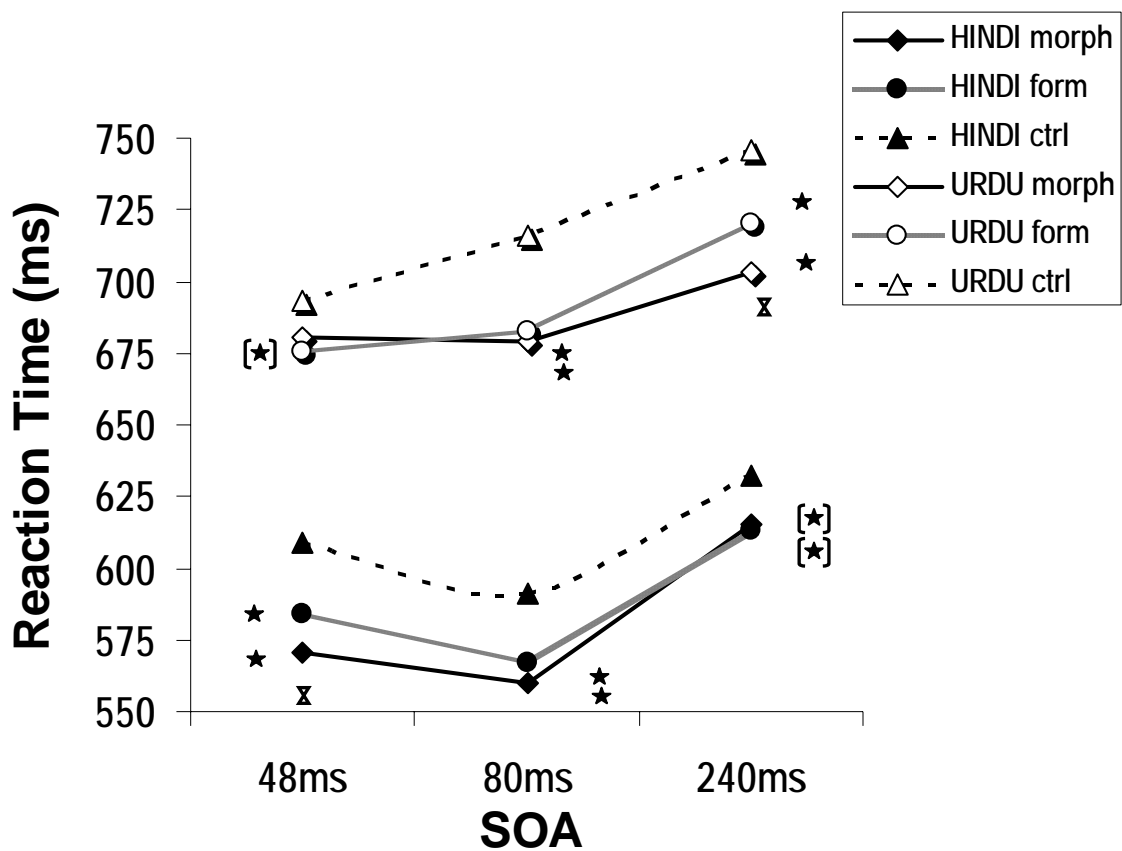


Figure 5 – Mean naming latencies in Exp. 1 as a function of Script, Prime Type, and SOA; priming relative to control (ctrl) indicated by * (participants and item ANOVA) and (**) (participant ANOVA only); superiority of morphological (morph) vs. form-overlap (form) condition in the ANOVA by-participants indicated by X ($p < .10$).

for the form condition relative to control [$F_1(1, 356) = 18.18, p < .05, MSE = 960.92, \eta^2 = .05; F_2(1, 924) = 6.29, p < .05, MSE = 4927.90, \eta^2 = .02$], but no difference was observed between them (both the by-participant and by-item analyses had $ps > .10$).

3. *Long SOA*. The long SOA setting revealed that in Hindi, the advantage over control persisted in the by-participants comparison for both morphological [$F_1(1, 356) = 4.75, p < .05, MSE = 960.92, \eta^2 = .01; F_2(1, 924) = 2.78, p < .10, MSE = 4927.90, \eta^2 = .01$] and form conditions [$F_1(1, 356) = 6.27, p < .05, MSE = 960.92, \eta^2 = .02; F_2(1, 924) = 3.50, p < .07, MSE = 4927.90, \eta^2 = .01$]. However, the morphological and form conditions did not differ ($ps > .10$). Urdu also exhibited morphological [$F_1(1, 356) = 31.42, p < .05, MSE = 960.92, \eta^2 = .08; F_2(1, 924) = 17.29, p < .05, MSE = 4927.90, \eta^2 = .06$] as well as form priming relative to control at the long SOA [$F_1(1, 356) = 11.56, p < .05, MSE = 960.92, \eta^2 = .03; F_2(1, 924) = 8.56, p < .05, MSE = 4927.90, \eta^2 = .03$]. Critically, the morphological condition proved superior to the form condition in the by-participant analysis, $F_1(1, 356) = 4.86, p < .05, MSE = 960.92, \eta^2 = .01; F_2 < 2$.

The Script by SOA interaction was further analyzed through contrasts of RT data collapsed across prime type, pitting short, medium and long SOA settings against one another separately for Hindi and Urdu. These tests showed that, in Hindi, the short vs. medium SOA

comparison was not significant (both by-participant and by-item analyses yielded $ps > .10$), whereas reliable differences emerged in comparisons of long SOA with short [$F_1 < 2$; $F_2(1, 308) = 10.36$, $p < .05$, $MSE = 5045.89$, $\eta^2 = .03$] as well as medium SOA settings [$F_1 < 2$; $F_2(1, 308) = 22.23$, $p < .05$, $MSE = 5045.89$, $\eta^2 = .07$]. Comparisons of the Urdu data likewise revealed no difference between short and medium SOA settings ($ps > .10$), but significantly slower responses at the long SOA as compared to both short [$F_1 < 2$; $F_2(1, 308) = 13.55$, $p < .05$, $MSE = 5045.89$, $\eta^2 = .04$] and medium SOA [$F_1 < 2$; $F_2(1, 308) = 7.22$, $p < .05$, $MSE = 5045.89$, $\eta^2 = .02$].

Discussion

The above experiment examined naming of Hindi and Urdu targets preceded by forward-masked morphological, form-related and control (unrelated) primes, presented at three different temporal points prior to the targets (48ms, 80ms and 240ms). Word naming accuracy in both languages was almost at ceiling level. Neither prime type nor SOA influenced accuracy significantly, but words were named faster and more accurately in Hindi than in Urdu. Importantly, by-participants' response latencies (RT) analysis yielded a reliable three-way interaction of script, prime type and SOA.

Further analyses showed that, at the short SOA (48ms), Hindi naming was facilitated by morphological and form primes, and naming latencies to targets preceded by morphological primes were faster than those preceded by form only related primes ($MD = 14\text{ms}$, $p = .09$). By contrast, Urdu naming latencies showed no effect of morphological relatedness but showed a significant advantage for form only related primes. At the medium SOA (80ms), both Hindi and Urdu showed priming relative to control in morphological as well as form conditions, but neither language exhibited differential effects of morphological vs. form primes; thus, the advantage of morphological over form priming found at the short SOA in Hindi was no longer evident at 80ms. At the long SOA condition (240ms) different priming patterns were again evident for Hindi and Urdu. Hindi showed priming for morphologically- and for form-related primes but there was no advantage for morphology over form; by contrast, Urdu showed faster latencies for targets preceded by morphologically related primes relative to those preceded by form related primes ($MD = 17\text{ms}$, $p < .05$).

The finding of differences in priming patterns for Hindi and Urdu supports the hypothesis that priming effects in Hindi and Urdu are attributable to a difference in orthographic depth rather than reflecting morphological processing, given that the two languages share a common morphological structure. Thus, superior, early-onset morphological

priming relative to form priming (under the masked prime presentation conditions of this experiment) was evident only in the shallow Hindi orthography. This pattern in Hindi mimicked earlier findings in English (McCormick et al., 2008; Rastle et al., 2000, 2004).

In contrast, Urdu exhibited no difference between morphological and unrelated primes at the short SOA. The facilitative effect of masked form primes at 48ms on Urdu target recognition contrasts with previous findings from Arabic and Hebrew of a lack of form priming at SOAs shorter than 50ms (Boudelaa & Marslen-Wilson, 2005; Frost et al., 2005). The disparity in these results in spite of the close resemblance of Urdu to Arabic orthography may be explained in terms of the extent of form overlap in the stimuli used by the respective studies. In the earlier Arabic and Hebrew studies, targets differed significantly from primes in their form, whereas targets in the present experiment were entirely embedded in their respective primes. Thus, the early form priming in Urdu may be comparable to the sub-lexical, form-based effects reported in studies of masked pseudoword priming (Forster, 1985; Masson & Isaak, 1999; Sereno, 1991).

The lack of a superiority in morphological over form priming at medium SOA in Hindi differs from the pattern observed in English—in the study by Rastle et al. (2000), for example, morphologically transparent prime-target pairs (*painter* – *paint*) showed robust priming

at short, medium and long SOAs of 43ms, 72ms and 230ms, respectively. However, the pattern in Hindi, where naming of target words preceded by masked morphological primes was faster than that for form primes only at the short SOA reinforces the argument that this early morphological superiority is due to morpho-orthographic decomposition. Recall that Rastle et al. (2000) demonstrated that morphologically opaque primes (*witness* – *wit*) were effective at the 43ms SOA, but not at 72ms or 230ms SOAs.

Priming at the medium SOA in Urdu had been hypothesized. The absence of a morphological priming advantage over form priming was, therefore, taken to reflect a lack of morphological priming. The observation of masked form priming at 80ms in Urdu corroborates Boudelaa and Marslen-Wilson's previous results for Arabic (2005), but the failure to find a morphological advantage in Urdu deviates from the finding in Arabic. The latter difference, however, may arise from the different morphological structure of Urdu and Arabic.

A greater effect of morphological over form-only priming in Urdu at the 240ms SOA (under masked conditions) conforms to the pattern documented in other languages such as English, German and Serbo-Croatian (Drews & Zwitserlood, 1995; Feldman & Andjelković, 1992; Feldman & Soltano, 1999; Rastle et al., 2000), whereas the Hindi results are in conflict with the established pattern. In Hindi, masked

morphological and form primes produced equivalent levels of facilitation at the long SOA. Two reasons were considered for this divergence of Hindi from the norm.

Previous work has shown that average word recognition latency in Hindi is 500ms to 600ms (Rao & Vaid, 2009; Vaid et al., 2007; 2008a, 2008b), as compared to the 300ms to 400ms range reported for English. From this difference, it may be reasoned that the 240ms SOA setting in the current experiment was insufficient for morpho-semantic processing of Hindi primes.

Further, to the extent that presentation of a forward mask reduces conscious prime visibility (by as much as 50ms, according to Forster, Mohan & Hector, 2003), prime processing in experiment 1 was additionally constrained. A second possibility is that forward masking selectively suppressed processing of Hindi as compared to Urdu targets; a more detailed treatment of this hypothesis is presented in a later section. Both explanations give rise to the prediction that eliminating the mask should allow more extensive processing of the prime, encouraging superior morphological priming in Hindi at the 240ms SOA. Experiment 2 tested this prediction, among others.

An unexpected result in Experiment 1 was the observation that naming latencies in both Hindi and Urdu were significantly longer at the long SOA than at the short and medium SOA settings. A tentative

explanation for this result is that primes exposed for 240ms (but not for 48ms and 80ms) may have been processed sufficiently to exercise a competitive, inhibitory effect on subsequently presented targets.

In sum, Experiment 1 demonstrated different patterns of morphological priming in Hindi vs. Urdu. Masked morphological primes exposed for 48ms facilitated Hindi naming more so than form-overlapping primes. For Urdu naming, superior morphological over form-based priming effect emerged only at the long SOA (240ms). The second experiment aimed to confirm the nature of the priming effects observed in Experiment 1.

EXPERIMENT 2: TIME COURSE OF MORPHOLOGICAL VS. FORM PRIMING IN NAMING HINDI AND URDU WORDS UNDER UNMASKED CONDITIONS

This experiment tested the hypothesis that early-onset, superior morphological priming in Hindi is morpho-orthographic in nature. Rastle and Davis (2008) postulated that a critical characteristic of morpho-orthographic processing in languages like English and French is its unconscious origin. Accordingly, it was predicted that the elimination of the forward mask, that is, the use of a consciously perceptible prime, would eliminate the superiority observed in Hindi for morphological over form priming at the short SOA.

Additionally, this experiment tested the explanation that the absence of superior morphological priming at the 240ms SOA in Hindi in Experiment 1 was due to insufficient prime processing. By using unmasked primes, Experiment 2 tested whether the increase in prime visibility would be sufficient to encourage superior morphological priming by 240ms in Hindi.

Finally, the current experiment aimed to examine the effect of unmasked primes on Urdu target recognition. A general prediction was that increased prime visibility would enhance priming effects in Urdu. Thus, it was expected that, unlike in Experiment 1, the use of

unmasked primes would produce an advantage for morphological relative to unrelated primes in Urdu at the short SOA.

Hence, the procedure of Experiment 2 dispensed with the forward mask. An additional modification to the design was the elimination of the medium SOA setting; participants were tested either at short or at long SOA.

Method

Participants. Thirty-two proficient bicultural readers of Hindi and Urdu were recruited from the same university. They included 22 males and 10 females ranging in age from 16 to 47, with an average age of 23. All used Hindi and Urdu daily; Hindi was the medium of instruction for most participants, and they had all studied Urdu at university level, in addition to learning both languages formally in elementary school and beyond. Their self-rated reading proficiency on a 7-point scale was 6.3 ($SD = 1.1$) in Hindi and 6.8 ($SD = 0.6$) in Urdu. Participants were paid per hour of involvement in the study.

Design, Materials and Procedure. A 2 (Script: Hindi, Urdu) by 3 (Prime Type: morphological, form, control) by 2 (SOA: 48ms, 240ms) mixed factorial design was used, with Script and Prime Type as repeated measures and SOA as a between-subjects factor. Participants were randomly assigned to the short SOA ($n = 17$) and long SOA conditions (n

= 15). Materials were the same as those used in Experiment 1. The procedure was also the same with the exception that the fixation cursor (presented for 800ms) was immediately followed by the prime (for 48 or 240 ms), with no intervening pattern mask. As in the previous experiment, participants were to name aloud the target words as quickly as possible.

Results

Table 3 shows participants' mean word naming accuracy, which was near ceiling in Hindi (97.6%) as well as Urdu (95.0%). After removing inaccurate responses, RT data were further trimmed of outliers (responses shorter than 250ms and longer than 1500ms), which resulted in elimination of 0.3% of the Hindi and 2.1% of the Urdu trials. Naming accuracy as well as RT were then analyzed separately in a mixed-design ANOVA by participants and by items. The by-participants analysis used a 2 (Script) \times 3 (Prime Type) \times 2 (SOA) design, with SOA as a between-subjects variable; the by-items analysis treated all three factors as within-item variables. Refer to Appendix D, Table D-2 for the complete ANOVA results.

The analysis of mean proportion correct responses revealed a significant main effect of Script indicating an advantage for Hindi over Urdu word naming, $F_1(1, 30) = 5.57, p < .05, MSE = 0.004, \eta^2 = .16; F_2(1,$

77) = 16.82, $p < .05$, $MSE = 0.014$, $\eta^2 = .17$. Neither Prime Type nor SOA exercised a reliable influence on accuracy (all $ps > .10$). Analysis of reaction time data likewise yielded a main effect of Script, indicating faster naming of Hindi than Urdu words [$F_1(1, 30) = 31.35$, $p < .05$, $MSE = 21975.35$, $\eta^2 = .51$; $F_2(1, 77) = 271.19$, $p < .05$, $MSE = 13021.35$, $\eta^2 = .78$]. A main effect of Prime Type also emerged [$F_1(1, 30) = 18.85$, $p < .05$, $MSE = 892.88$, $\eta^2 = .39$; $F_2(1, 77) = 16.79$, $p < .05$, $MSE = 8623.70$, $\eta^2 = .18$]. SOA was significant only in the analysis by-items ($p_1 > .10$; $p_2 < .05$). The effect of SOA was modified by an interaction with Script in the by-item ANOVA, $F_1 < 1$; $F_2(1, 77) = 7.48$, $p < .05$, $MSE = 12005.29$, $\eta^2 = .09$.

To examine for morphological superiority relative to control as well as form conditions, planned comparisons were computed separately on the RT data per Script and SOA setting, using a family-wise $\alpha = .004$. These tests revealed no facilitation of targets preceded by morphologically related primes relative to those preceded by control or form-related primes at the short SOA in Hindi (all $ps > .10$). The by-participant analysis revealed a marginal advantage for form relative to control conditions, $F_1(1, 120) = 4.61$, $p < .04$, $MSE = 788.03$, $\eta^2 = .04$; $F_2(1, 616) = 2.49$, $p = .12$, $MSE = 8855.46$, $\eta^2 = .01$. In contrast, a significant advantage for the morphological over control conditions was obtained by-participants at the short SOA in Urdu [$F_1(1, 120) = 14.54$, p

$< .004$, $MSE = 788.03$, $\eta^2 = .11$; $F_2(1, 616) = 6.70$, $p < .01$, $MSE = 8855.46$, $\eta^2 = .02$]. The form condition also emerged superior to control in the by-participants analysis [$F_1(1, 120) = 10.98$, $p < .004$, $MSE = 788.03$, $\eta^2 = .08$; $F_2(1, 616) = 5.25$, $p < .05$, $MSE = 8855.46$, $\eta^2 = .02$]. However, morphological priming was not superior to form priming ($ps > .10$).

At the long SOA, Hindi exhibited a clear advantage for the morphological condition with respect to control in both by-participants

Table 3

Exp. 2: Participants' word naming latency (RT) and proportion accuracy to Hindi vs. Urdu targets preceded by morphologically-related (Morph), form-overlapping (Form) and unrelated (Control) primes ($n = 32$)

Prime			Hindi		Urdu	
SOA (ms)	Type	N	Mean RT	Accuracy	Mean RT	Accuracy
Short	Morph	17	606 (19) ¹	0.98 (0.01)	699 (31)	0.95 (0.02)
	Form	17	600 (19)	0.98 (0.01)	704 (26)	0.95 (0.01)
	Control	17	621 (18)	0.97 (0.01)	736 (30)	0.93 (0.02)
Long	Morph	15	610 (19)	0.97 (0.01)	755 (33)	0.95 (0.01)
	Form	15	637 (27)	0.97 (0.02)	763 (34)	0.95 (0.01)
	Control	15	651 (24)	0.95 (0.02)	789 (33)	0.95 (0.01)

¹Standard error values italicized in parentheses.

and by-items comparisons, $F_1(1, 120) = 15.77, p < .004, MSE = 788.03, \eta^2 = .12$; $F_2(1, 616) = 9.94, p < .004, MSE = 8855.46, \eta^2 = .03$. No priming was observed in the form condition (both $ps > .10$). Importantly, at the long SOA, the morphological condition was marginally superior to the form condition, $F_1(1, 120) = 6.93, p < .05, MSE = 788.03, \eta^2 = .06$; $F_2(1, 616) = 3.62, p < .07, MSE = 8855.46, \eta^2 = .01$.

Urdu continued to exhibit an advantage relative to control in the morphological condition [$F_1(1, 120) = 10.82, p < .004, MSE = 788.03, \eta^2 = .08$; $F_2(1, 616) = 15.24, p < .004, MSE = 8855.46, \eta^2 = .04$], and the form condition was faster than the control as well [$F_1(1, 120) = 6.40, p < .05, MSE = 788.03, \eta^2 = .05$; $F_2(1, 616) = 12.22, p < .004, MSE = 8855.46, \eta^2 = .04$]. However, the form condition did not differ reliably from the morphological condition ($ps > .10$). See Figure 5 for an illustration of the differences in priming effects between Hindi and Urdu.

The Script by SOA interaction was probed by computing simple effects ANOVA separately for Hindi and Urdu RT data collapsed across priming conditions. No difference between short and long SOA settings emerged in either comparison in Hindi ($ps > .10$), whereas Urdu revealed significantly shorter naming latencies at the short as compared to the long SOA in the comparison by items, $F_1 < 1$; $F_2(1, 154) = 49.24, p < .05, MSE = 10724.70, \eta^2 = .10$.

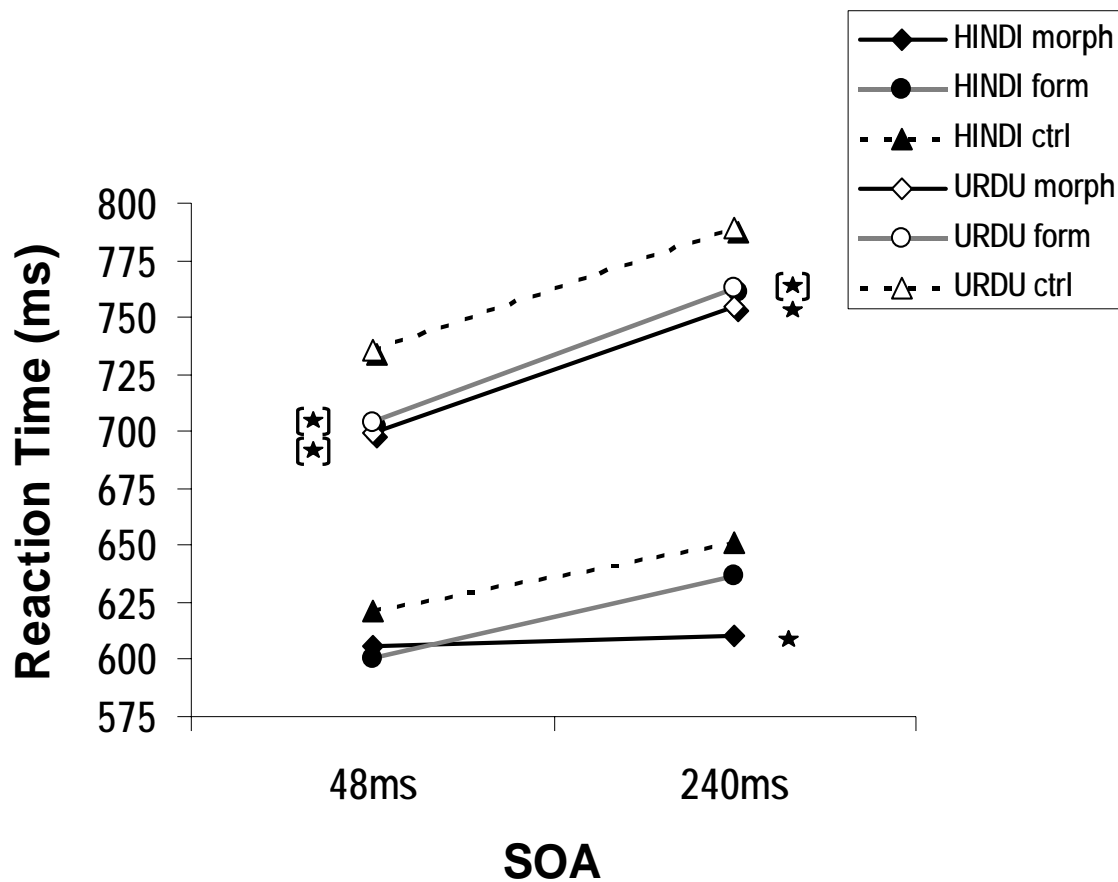


Figure 6 – Participants' mean naming latencies for Hindi and Urdu under unmasked priming conditions as a function of SOA and Prime Type (Exp. 2); priming ($p < .004$) relative to control indicated by * (participant and item ANOVA) and (*) (ANOVA by-participants or by-items only).

Discussion

In this experiment, unmasked primes were used to compare facilitation of word naming in Hindi and Urdu by morphologically related words as opposed to form-overlapping and unrelated controls, using prime-target SOA settings of 48ms (short) and 240ms (long). As in

Experiment 1, participants' performance revealed both greater accuracy and faster responses to words presented in Hindi than in Urdu. Naming accuracy was uniform across priming conditions and SOA but these factors significantly influenced response latency.

Planned comparisons showed that at the short SOA morphologically related primes did not facilitate Hindi word naming; an advantage was observed for the form condition relative to control. In contrast, at the long SOA there was an effect of morphological priming but no effect of form priming.

The Hindi results thus supported the prediction that removal of the forward mask would eliminate early-onset morphological priming. The lack of priming by unmasked morphological primes at the short SOA reinforces the view that the priming recorded in Experiment 1 was the outcome of early and unconscious processing; that is to say, early-arising, superior morphological priming in Hindi conformed to the characteristics of morpho-orthographic decomposition. Further, facilitation of Hindi word naming by unmasked morphological primes at the 240ms SOA supports the hypothesis that forward masking constrains morpho-semantic processing in Hindi.

In Experiment 2, Urdu words primed by unmasked morphological as well as form-overlapping cues were named significantly faster than those preceded by unrelated primes at the short SOA. The absence of a

priming effect in Experiment 1 for Urdu words at the short SOA condition suggests that inclusion of a forward mask constrains lexical processing in the orthographically deep Urdu script. At the long SOA also, Urdu word naming was facilitated equally by unmasked morphological and form primes; the lack of a statistical difference between morphological and form conditions suggests that the removal of the mask diminished the advantage of morphological over form primes. Further evidence is needed, however, before this interpretation can be accepted.

The comparison of naming latencies at short vs. long SOA in Experiment 2 revealed a disadvantage for the latter only in Urdu. Thus, the significant disadvantage of the long SOA in comparison with short and medium SOAs that emerged in Experiment 1 was only partly replicated in the present data. When discussing Experiment 1, it was suggested that competition between primes and targets may have been responsible for the slower naming latencies recorded at the 240ms SOA. Following this reasoning, it is suggested that unmasked primes induced uniformly inhibitory effects on targets at short as well as at long SOAs in the orthographically shallow Hindi script, whereas inhibition by orthographically deep Urdu primes became evident only by the long SOA. This explanation is purely speculative at present, and requires independent confirmation.

Taken together, the findings from this experiment suggest that removal of a forward mask uncovered evidence for early-arising morphological priming in Hindi which was consistent with the morpho-orthographic decomposition view proposed by Rastle and Davis (2008), and subsequent morpho-semantic processing, given that morphological (but not form) priming was obtained at the long SOA. In contrast, unmasked primes facilitated recognition of Urdu targets in morphological and form conditions equally, at both the short and long SOA conditions, suggesting that the effect could reflect form overlap rather than morphological priming.

EXPERIMENT 3: ROLE OF MASKING AND FORM OVERLAP IN HINDI AND URDU MORPHOLOGICAL PRIMING

The third experiment sought to replicate and extend the findings of Experiments 1 and 2. The first two experiments demonstrated a clear divergence in the pattern of morphological priming between Hindi and Urdu. Whereas Hindi exhibited superior morphological priming under masked priming conditions at a brief prime-target SOA of 48ms, the effect was absent under identical conditions in Urdu. By contrast, removal of the forward mask led to the disappearance of priming at the 48ms SOA in Hindi, while Urdu exhibited form-based facilitation from unmasked primes exposed for 48ms. A further difference recorded between the two languages lay in the effect of masking on morphological priming at the 240ms SOA: Urdu exhibited a clear morphological advantage under these conditions, whereas Hindi did not. Elimination of the forward mask encouraged a morphological advantage in Hindi but not in Urdu at the 240ms SOA.

Experiment 3 had two major goals. The first goal was to determine the nature of the difference in morphological priming between Hindi and Urdu. The issue here is whether differences in the masked morphological priming patterns of Hindi and Urdu may arise from a simple delay or lag in processing of the computationally more

demanding Urdu script (which is phonologically opaque and visuospatially complex) as compared to the phonologically transparent Hindi script. Experiment 3 focused on the role of forward masking in mediating morphological priming in Hindi and Urdu. Since the critical difference between Hindi and Urdu in Experiments 1 and 2 hinged on the presence vs. absence of the forward pattern mask, Exp. 3 included masking as a variable in order to systematically examine its influence on morphological priming.

A second goal of this experiment was to replicate the results of Experiments 1 and 2 using a different set of stimuli. This goal was motivated by the question of whether morphological priming in Hindi and Urdu, and especially early-arising priming in Hindi, is resistant to changes in surface form. Previous research by McCormick et al. (2008) demonstrated that morpho-orthographic priming in English is resistant to differences in the orthographic and phonological overlap between words. Morphologically opaque pairs in their study generated greater priming than form-only overlapping pairs (e.g., *shovel* – *shove*), irrespective of whether the words were highly similar (e.g., *committee* – *commit*) or dissimilar in form (e.g., *palatial* – *palate*). In the review by Rastle and Davis (2008), resilience to differences in surface form was considered a determining characteristic of morpho-orthographic analysis.

Research in several languages has demonstrated the immunity of morphological priming at longer prime-target intervals to changes in surface form. Thus, at long intervals, morphologically transparent primes that are similar in form (e.g., *healer* – *heal*) as well as dissimilar in form (*health* – *heal*) have been found to facilitate target recognition equally in English, French, Hebrew and Spanish (Allen & Badecker, 1999; Bentin & Feldman, 1990; Feldman & Fowler, 1987; Fowler et al., 1985; Grainger, Colé & Seguí, 1991; Stolz & Feldman, 1995).

The current experiment tested the resilience of morphological priming in Hindi and Urdu to variations in surface form by using targets that were not embedded within primes. That is, whereas targets used in Experiments 1 and 2 were single syllable words that were identical to the first syllable of the primes, e.g., *trickster* – *trick* (morphological) vs. *trickle* – *trick* (form-overlapping), targets in Experiment 3 were bi- or tri-syllabic, with only the first syllables of the prime and target overlapping in form, analogous to *singing* – *singer* (morphological) vs. *single* – *singer* (form-overlapping).

Following the logic of the first two experiments, it was expected that the pattern of morphological priming in Hindi would resemble that of English and other Indo-European languages. In particular, Hindi was expected to reveal an early-arising morphological superiority when primes were masked and exposed for a short SOA of 48ms. On the other

hand, Urdu was expected to show morphological priming only after sufficient conscious processing of the prime, that is, at the longer prime-target SOA of 240ms.

A corollary aim of Experiment 3 was to investigate whether the orthographically deep Urdu script would reveal masked form priming at the 48ms SOA even though the targets no longer completely overlapped in form with the primes. It should be recalled here that in Experiment 1, an ad hoc explanation suggested for the finding that masked, form-overlapping primes facilitated Urdu target recognition at the 48ms SOA ascribed the result to complete form overlap between primes and targets. To support this explanation, Experiment 3 should show no form-related priming.

Similarly to Experiments 1 and 2, targets in the current experiment were each paired with three primes, morphological, form-overlapping (henceforth simply *form*) and unrelated/control primes; unrelated primes were chosen to be completely dissimilar to the targets in form as well as meaning. As outlined above, the targets in the present experiment did not fully overlap in form with either the morphological or the form-related primes. (Refer to Table 4 for examples of stimuli.)

Primes were exposed for either a brief duration of 48ms (short SOA) or for 240ms (long SOA). The use of a forward mask was additionally manipulated by testing one group of readers with masked

primes, and a second group with fully visible primes. As outlined above, it was expected that superior morphological priming at the short SOA would be limited to Hindi, and observable only under masked priming conditions. By contrast, both Hindi and Urdu were expected to support morphological priming at the long SOA, although it was anticipated that Hindi might reveal significant morphological priming at 240ms only with unmasked primes, thus replicating the contrast in Experiments 1 and 2.

Method

Participants. Eighty-one proficient readers of Hindi and Urdu were recruited from a university in northern India, including 62 males and 19 females with an average age of 24 (age range 16 to 47 years).

Participants used both languages on a daily basis, and most had received formal instruction in Hindi and Urdu at the elementary school level and beyond. Hindi was the medium of instruction of most participants at university level, and they had all studied Urdu at the university. Their self-rated reading proficiency was 6.4 ($SD = 1.0$) in Hindi and 6.8 ($SD = 0.6$) in Urdu, on a 7-point scale.

Fifty-one readers were tested using forward-masked primes (Group 1), while thirty were tested using unmasked primes (Group 2). In the first group (masked primes), 26 readers were tested at short SOA and 25 at long SOA, while 15 readers were tested at each SOA setting in

Table 4

Example of Prime-Target pair used in Experiments 3 and 5.

	Target	Priming Conditions		
		Morphological	Form	Control
Hindi	चुराए	चुराया	चुकाना	कपड़ा
Urdu	چُرَا اے	چُرَا یا	چُکَا نا	کپڑا
Pronunciation	/ʈʊrāe/	/ʈʊrāyā/	/ʈʊkānā/	/kapʈā/
Meaning	<i>they stole</i>	<i>s/he stole</i>	<i>to repay</i>	<i>cloth</i>
Analogy	<i>SINGER</i>	<i>SINGING</i>	<i>SINGLE</i>	<i>HOSTEL</i>

the second group (unmasked primes).

Design and Materials. The experiment utilized a 2 (Script: Hindi, Urdu) by 3 (Prime Type: morphological, form, control) by 2 (SOA: 48ms, 240ms) by 2 (Masking: forward mask, no mask) mixed factorial design. Script and Prime Type were repeated variables, while SOA and Masking were between-subjects variables. Stimuli included 48 targets (43 two-syllable and 5 three-syllable words), each paired with three words

corresponding to the priming conditions, making a total of 144 primes⁴; primes were either two or three syllables in length. All words were of medium frequency in Hindi/Urdu, and subjective ratings obtained from small groups of raters (12 to 14 per word) as a manipulation check yielded average ratings of 4.2 ($SD = 1.3$) for targets in Hindi, and 4.9 ($SD = 1.2$) in Urdu. Primes were rated 4.6 ($SD = 1.4$) and 5.2 ($SD = 1.1$) respectively in Hindi and Urdu⁵. Due to the constraints on selection of stimuli, word-class could not be controlled. Refer to Appendix C for a full description of stimuli, including word-class and frequency.

Stimuli were presented as bitmap images (white text on black background), prepared from Hindi words typed in Myhindigyan font, size 20, and Urdu typed in Nastaliq font, size 18. An additional set of 64 words of similar syllable length and complexity was included, to make up 32 filler prime-target pairs.

Procedure. Stimuli were presented using E-Prime experimental software (Psychological Software Tools Inc., 2003) in a speeded naming task. Participants in Group 1 were administered trials identical to those

⁴ Data from an additional set of 48 primes which shared limited morphological as well as form overlap with targets are not reported here, owing to the poor accuracy and extremely long response latencies generated in this condition.

⁵ Separate ANOVA of average frequency ratings in Hindi and Urdu revealed significant differences among prime types in both languages, and Tukey's HSD tests revealed that control primes received significantly higher frequency ratings compared to morphological and form primes in Hindi as well as Urdu. However, an inflated priming effect arising from inhibition of control targets by higher frequency primes was ruled out by comparing latencies to control targets paired with high vs. low frequency primes (prime grouping based on median split), which revealed no difference between targets paired with high and low frequency control primes in either Hindi or Urdu.

in experiment 1, with a forward pattern mask exposed prior to the prime. Testing procedure for the second group was identical to that in experiment 2.

Both groups saw half the experimental targets (24) in Hindi and half in Urdu, in blocks of 40 trials each (24 experimental, 16 fillers). Within a block, an equal number of targets were paired with morphological, form and control primes, with multiple versions of the experiment created to ensure that each target was presented once each with its three different primes in each language. Assignment of participants to different versions was random, and language order was counterbalanced, such that no participant saw a word more than once.

Results

Mean proportion accuracy of participants' word naming responses was computed for each cell of the experiment, and showed overall higher accuracy in Hindi (95.6%) as compared to Urdu (91.3%). After eliminating inaccurate trials, RT data were further trimmed of outliers (responses shorter than 250ms and longer than 1750ms), resulting in removal of 0.9% of Hindi and 5.0% of Urdu trials. The remaining data revealed an RT advantage for Hindi over Urdu ($MD = 148ms$), see Table 5.

Analyses of variance for the 2 (Script) \times 3 (Prime Type) \times 2 (SOA) \times 2 (Masking) experiment were computed separately for participant and

item⁶ means, on accuracy as well as RT data. In the by-participant ANOVA, Script and Prime Type were within-subject variables, while SOA and Masking were between-subject variables; the ANOVA of item means treated all factors as repeated or within-item variables. Refer to Appendix D, Tables D-3 (accuracy) and D-4 (RT) for ANOVA results.

Naming Accuracy. The accuracy analysis revealed significant main effects of Script and Masking (all $ps < .05$). These effects were modified by a three-way interaction of Script, SOA and Masking, $F_1(1, 77) = 7.38$, $p < .05$, $MSE = 0.008$, $\eta^2 = .09$; $F_2(1, 47) = 5.38$, $p < .05$, $MSE = 0.028$, $\eta^2 = .10$. No reliable effect emerged for either Prime Type or SOA (all $ps > .05$). However, a Script by Prime Type interaction was found to be significant by-participants, $F_1(2, 154) = 3.92$, $p < .05$, $MSE = 0.008$, $\eta^2 = .05$; $F_2(1, 47) = 2.77$, $p < .07$, $MSE = 0.024$, $\eta^2 = .06$. The interaction of Script with Prime Type was examined further in tests of simple effects, which revealed a near significant effect of Prime Type for Urdu naming accuracy in the by-participants comparison [$F_1(2, 308) = 2.81$, $p = .06$, $MSE = 0.010$, $\eta^2 = .02$; $F_2 < 1$]. The effect indicated that both morphological and form prime conditions in Urdu facilitated accuracy relative to control primes. There was no effect of Prime Type for Hindi naming (both $ps > .10$).

⁶ Missing values in the item analyses were *imputed* following the procedure outlined in Steele and Torrey (1980).

Table 5

Exp. 3: Participants' word naming latency (RT) and proportion accuracy to Hindi vs. Urdu targets preceded by masked vs. unmasked morphological (Morph), form-overlapping (Form) and unrelated (Control) primes (n = 81)

Group 1	Prime		Hindi		Urdu	
(Fwd Mask)	Type	N	Mean RT	Accuracy	Mean RT	Accuracy
Short SOA	Morph	26	639 (24) ¹	0.96 (0.01)	744 (38)	0.89 (0.02)
	Form	26	649 (21)	0.91 (0.02)	767 (34)	0.93 (0.02)
	Control	26	680 (26)	0.94 (0.02)	810 (44)	0.91 (0.03)
Long SOA	Morph	25	738 (36)	0.97 (0.02)	833 (46)	0.92 (0.02)
	Form	25	784 (37)	0.95 (0.02)	845 (39)	0.90 (0.03)
	Control	25	768 (39)	0.97 (0.01)	885 (50)	0.85 (0.03)
Group 2						
(No Mask)						
Short SOA	Morph	15	758 (29)	0.97 (0.02)	897 (51)	0.94 (0.03)
	Form	15	753 (33)	0.97 (0.02)	904 (55)	0.91 (0.04)
	Control	15	742 (26)	0.97 (0.02)	951 (63)	0.89 (0.04)
Long SOA	Morph	15	779 (36)	0.96 (0.03)	1032 (61)	0.98 (0.02)
	Form	15	828 (42)	0.94 (0.03)	1001 (46)	0.97 (0.02)
	Control	15	833 (38)	0.99 (0.01)	1060 (55)	0.93 (0.03)

¹Standard error values italicized in parentheses.

The three-way Script by SOA by Masking interaction was similarly examined in a series of contrasts. These contrasts revealed no difference in Hindi accuracy between the forward mask and no mask conditions at either short or long SOA (all F s < 1). Urdu naming accuracy at the short SOA was also equivalent across the forward and no mask conditions (both F s < 1); at the long SOA, however, the no mask condition exhibited marginally higher accuracy in naming Urdu words than the forward mask condition, $F_1(1, 154) = 3.39, p = .09, MSE = 0.013, \eta^2 = .02$; $F_2(1, 188) = 3.28, p = .08, MSE = 0.030, \eta^2 = .02$.

Naming Latency. Naming latency was similarly analyzed in a 2 (Script) \times 3 (Prime Type) \times 2 (SOA) \times 2 (Masking) ANOVA after eliminating incorrect and outlier trials (see criteria at the beginning of the results description). The RT analyses revealed main effects of all four variables—Script, Prime Type, SOA and Masking (all p s < .05). These effects were qualified by the following two-way interactions: the ANOVA by-participants yielded a significant Script by Prime Type interaction, $F_1(2, 154) = 3.03, p < .05, MSE = 6014.17, \eta^2 = .04$; $F_2 < 1$. A reliable interaction of Script with Masking also emerged [$F_1(1, 77) = 5.63, p < .05, MSE = 38382.37, \eta^2 = .07$; $F_2(1, 47) = 31.17, p < .05, MSE = 14812.93, \eta^2 = .40$], and was further modified in the by-items analysis by a three-way interaction of Script, SOA and Masking, $F_1 < 2$; $F_2(1, 47) = 5.43, p < .05, MSE = 21136.12, \eta^2 = .10$.

Tests of simple effects were conducted to examine the interaction of Script with Prime Type, and comparisons by-participants revealed that Prime Type exercised a reliable influence on Urdu word naming latency [$F_1(2, 308) = 8.60, p < .05, MSE = 7465.76, \eta^2 = .05; F_2 < 2$], but had only a marginal influence on Hindi [$F_1(2, 308) = 2.83, p = .06, MSE = 7465.76, \eta^2 = .02; F_2 < 1$]. Similar simple effects tests of the Script by Masking interaction revealed that, although naming latencies were faster under the forward mask condition in both languages, the advantage was statistically significant only in the by-items analysis in Hindi [$F_1 < 2; F_2(1, 94) = 5.69, p < .05, MSE = 17736.38, \eta^2 = .06$], whereas Urdu exhibited a robust advantage for the forward mask condition both by-participants and by-items [$F_1(1, 154) = 5.65, p < .05, MSE = 86204.32, \eta^2 = .04; F_2(1, 94) = 28.41, p < .05, MSE = 17736.38, \eta^2 = .23$].

This result was probed further by examining the three-way Script by SOA by Masking interaction in the item-wise means. Separate contrasts of the forward mask vs. no mask conditions were computed per Script and SOA setting on naming latencies averaged across Prime Type. Results of these tests were as follows: at the short SOA, the by-items comparison revealed faster naming of Hindi words under the forward mask compared to the no-mask condition [$F_1 < 1; F_2(1, 188) = 11.18, p < .05, MSE = 17362.20, \eta^2 = .06$]. At the long SOA, Hindi

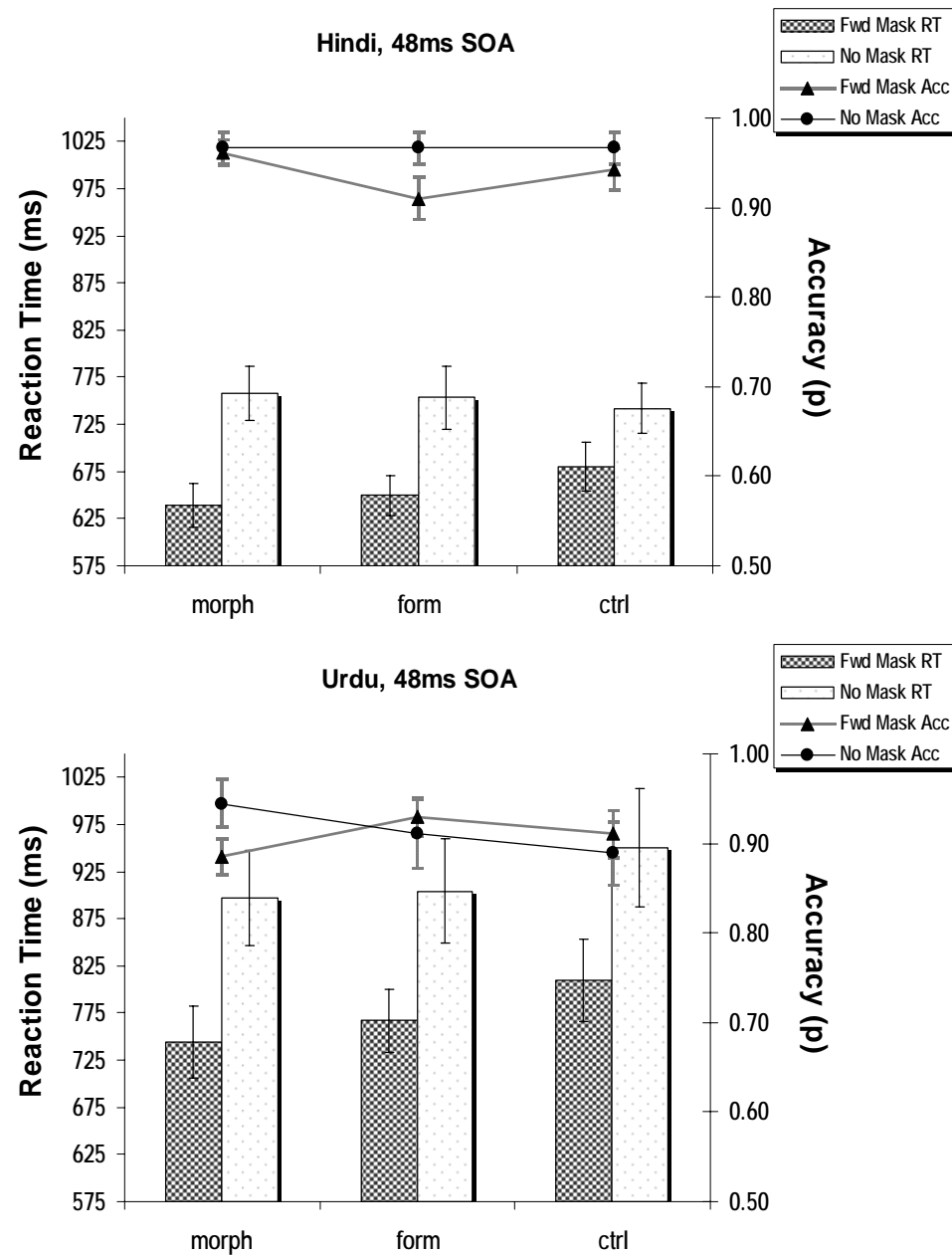


Figure 7 – Combined graphs of participants' Reaction Time (left y-axis, column graphs) and accuracy (right y-axis, line graphs) in Exp. 3; first two panels above show 48ms SOA, with performance in Hindi (top) and Urdu (bottom).

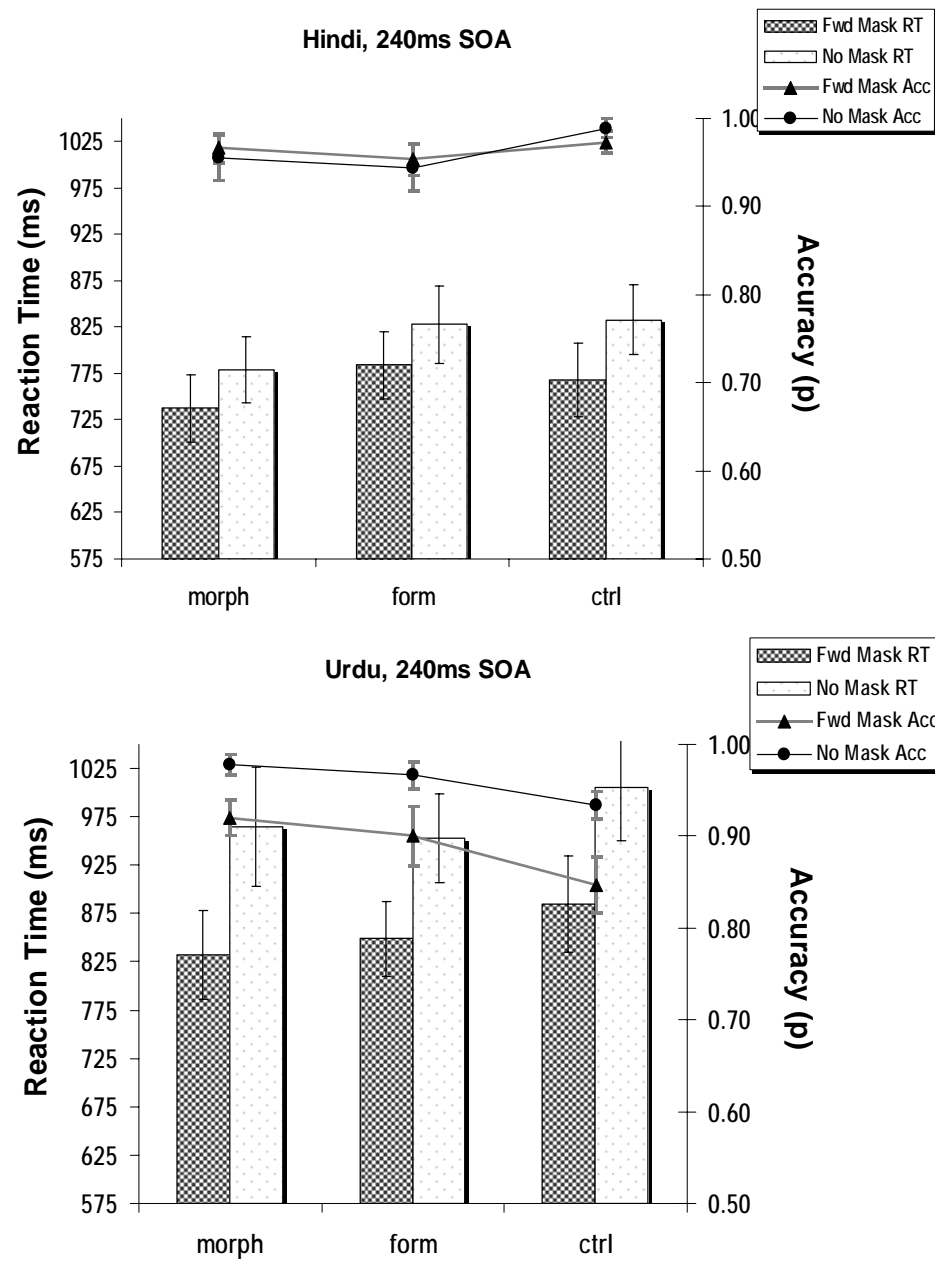


Figure 7 (continued) – third and fourth panels show performance at 240ms SOA.

showed no difference between forward mask and no mask conditions ($ps > .10$).

Urdu naming latencies at the short SOA were also faster under the forward mask as opposed to the no mask condition; this difference proved marginally significant by-participants, but reliable by-items [$F_1(1, 154) = 2.28, p < .09, MSE = 86204.32, \eta^2 = .02$; $F_2(1, 188) = 23.38, p < .05, MSE = 17362.20, \eta^2 = .11$]. A similar pattern emerged in Urdu at long SOA [$F_1(1, 154) = 3.36, p < .07, MSE = 86204.32, \eta^2 = .02$; $F_2(1, 188) = 35.28, p < .05, MSE = 17362.20, \eta^2 = .16$].

To assess the effect of priming within each script, separate complex contrasts were additionally computed on Hindi and Urdu naming latencies for data averaged across SOA and Masking (family-wise $\alpha = .008$); these tests compared morphological and form conditions against the control condition and against each other. Results revealed that in Hindi, the morphological condition was marginally superior (by-participants) over the control condition [$F_1(1, 308) = 4.77, p < .03, MSE = 7465.76, \eta^2 = .02$; $F_2 < 1$], as well as with respect to the form condition [$F_1(1, 308) = 3.65, p < .06, MSE = 7465.76, \eta^2 = .01$; $F_2 < 1$]. No difference emerged in Hindi naming latencies between the form and control conditions (both $F_s < 1$). Urdu revealed a significant advantage by-participants for the morphological condition over the control $F_1(1, 308) = 14.80, p < .008, MSE = 7465.76, \eta^2 = .05$; $F_2(1, 188) = 2.16, p$

= .14, $MSE = 29734.13$, $\eta^2 = .01$] and also for the form condition with respect to the control condition [$F_1(1, 308) = 10.66$, $p < .008$, $MSE = 7465.76$, $\eta^2 = .03$; $F_2 < 2$], although morphological and form conditions did not differ from each other (both $F_s < 1$). Refer to Figure 7 for the interaction of Script, Prime Type, SOA and Masking in Hindi and Urdu word naming latency as well as accuracy.

Discussion

This experiment compared morphological priming in Hindi and Urdu for prime-target pairs that partially differed in surface form. Both primes and targets in the present experiment were words of either two or three syllables. As in Experiments 1 and 2, morphological priming was compared with respect to an unrelated control condition as well as a form-only overlap condition. The effect of prime presentation condition on morphological priming was studied in this experiment by varying prime-target SOA as well as forward masking of the prime—primes were presented either for a very brief duration of 48ms (short) or for 240ms (long), and were either preceded by a 500ms pattern mask (forward mask) or were presented unmasked (no mask).

The results from this experiment revealed faster and more accurate naming of words presented in Hindi than in Urdu, consistent with the pattern established in previous experiments. Accuracy at

naming Hindi words was not influenced by prime type, SOA or masking, whereas Urdu targets preceded by morphological ($MD = 3.7\%$) as well as form primes ($MD = 3.2\%$) elicited marginally higher accuracy compared to the control condition. Further, at the long SOA, Urdu naming accuracy was marginally higher with unmasked as opposed to masked primes ($MD = 7.0\%$).

Word naming latencies (RT) revealed further divergence between Hindi and Urdu. Although not statistically significant, Hindi RT revealed a small advantage for the morphological condition relative to control as well as form conditions. By contrast, a significant advantage emerged for both morphological and form conditions with respect to the control condition in Urdu, although the two former conditions did not differ. A three-way interaction of script, SOA and masking revealed that the masking effect was limited to the short SOA in Hindi, whereas Urdu showed a consistent effect of masking at short as well as long SOA.

The interaction of script, SOA and masking in the above results provide clear support for the hypothesis that, rather than arising out of a lag effect, differences between Hindi and Urdu in masked morphological priming reflect qualitatively distinct processing strategies. This argument is further strengthened by the contrasting effects of masking on morphological vs. form conditions at the short SOA in Hindi vs. Urdu (see discussion below).

A combined consideration of RT and accuracy data in the current experiment is essential to understand the dissociation in the effects of prime type, SOA and masking on Hindi and Urdu word recognition. From the first and second graphs in Figure 7, it can be seen that at the 48ms SOA, masking exercised opposite effects on morphological and form conditions in Hindi (top panel) vs. Urdu (bottom panel). Although Hindi naming latencies in morphological as well as form conditions were faster than control under masked prime presentation, only the morphological condition exhibited superior speed and accuracy when compared to unmasked prime presentation. The pattern was reversed in Urdu, where masked *form* primes encouraged superior speed as well as accuracy but masked morphological primes yielded a speed-accuracy tradeoff. This contrast highlights a trend whereby masked morphological primes exerted a facilitative influence on Hindi but not on Urdu word recognition at the 48ms SOA.

Similarly, the third and fourth graphs in Figure 7 illustrate a marked difference in the effect of masking on Hindi (top panel) and Urdu (bottom panel) word naming at the 240ms SOA. No effect of masking was evident in either naming latency or accuracy in Hindi, although a slight advantage for masked morphological primes was found relative to form primes ($p < .09$, family-wise $\alpha = .002$). On the other hand, the forward mask stimulated faster but less accurate responses overall in

Urdu. However, since neither masked nor unmasked prime presentation revealed a significant speed-accuracy tradeoff⁷ at the long SOA, Urdu data were further scrutinized for evidence of morphological effects.

Remarkably, Urdu naming accuracy was uniform across the three prime type conditions under unmasked presentation, and a slight advantage in naming latency emerged for the form condition relative to control ($p < .07$, family-wise $\alpha = .002$). An advantage for the morphological over control conditions was found only under masked priming conditions in both accuracy ($p < .02$, family-wise $\alpha = .002$) and naming latency ($p < .04$, family-wise $\alpha = .002$). The results at the 240ms SOA indicate a similar trend towards superior facilitation of word recognition in Urdu by morphological primes.

The proposed differences between Hindi and Urdu notwithstanding, it remains the case that morphological priming effects in Exp. 3 were not as clearly evident as they were in the previous experiments. While it could be argued that heterogeneity of the stimuli in this experiment could have diluted priming effects, this argument would be inconsistent with the results of experiments 1 and 2, where

⁷ Following Eviatar and Ibrahim (2007), the Urdu data were checked for possible speed-accuracy trade-offs by computing Pearson correlation coefficients of latency vs. accuracy on individual cells—these tests revealed no significant correlations at long SOA in the forward mask condition. (At short SOA, the forward mask condition revealed a marginal speed-accuracy tradeoff for morphological targets, with $r(26) = -.33$, $p = .10$; at long SOA, the no mask condition yielded a marginal positive correlation for morphological targets, $r(15) = .49$, $p = .07$.)

similar variations among stimuli in word class and morphological process (inflection vs. derivation) did not preclude priming.

A second, more plausible, explanation for the relative lack of morphological priming in Experiment 3 relates to the use of two- and three-syllable words in this experiment (whereas the previous two experiments had monosyllabic targets). Other studies of word recognition in Hindi and Urdu have pointed to a differential interaction of syllable length with script (Vaid et al., 2008a).

Another possibility is that morphological priming in Hindi and Urdu is affected by the degree of form similarity between primes and targets, with weaker priming occurring for prime-target pairs that show less form overlap than for those sharing more overlap. However, this explanation is inconsistent with evidence from other languages that shows morphological effects to be resilient to surface form variation (Allen & Badecker, 1999; Bentin & Feldman, 1990; Boudelaa & Marslen-Wilson, 2005; Feldman & Moskovljević, 1987; Fowler et al., 1985; Grainger et al., 1991), and also contrasts with evidence that morpho-orthographic effects are robust to changes in form (McCormick et al., 2008).

Further investigation is necessary in order to test whether syllable length or degree of form similarity is the primary contributor to the weakened morphological priming observed in Experiment 3. To test

these competing hypotheses, morphological priming might be compared using a single prime, such as /mo□nā/ (*to turn*) paired with three types of targets—one-syllable, form similar, e.g., /mo□/ (*turn*), one-syllable, form dissimilar, e.g., /mu□/ (*be turned*) and two-syllable, form similar, e.g., /mu□kar/ (*having turned*). Such a design would be analogous to comparing the effect of *drinker* on the recognition of *drink*, *drunk* and *drinking*. If syllable length is the critical factor, *drinker* should prime *drink* and *drunk* but not *drinking*; if form similarity determines priming, *drink* and *drinking* should show priming but not *drunk*.

It is important to note that what Experiment 3 did show was that masking exerted qualitatively different effects on word recognition in Hindi and Urdu. Specifically, at the short SOA, masking enhanced the speed of processing morphologically primed words in Hindi without reducing naming accuracy; in contrast, masking enhanced the speed of processing form-primed words and control primes but was associated with a reduced accuracy for targets preceded by form- or control primes. For Urdu words at the short SOA condition, masking did not facilitate morphological processing but rather appeared to encourage superior facilitation by form primes. Masking effects were not evident at the 240ms SOA in Hindi, whereas in Urdu, masked morphological primes elicited slightly faster and more accurate responses compared to form-overlapping and unrelated primes.

GENERAL DISCUSSION

The foregoing section presented three experiments conducted to investigate the role of orthographic depth in mediating morphological priming in Hindi vs. Urdu. It was hypothesized that if morphological processing strategy is a product solely of the morphological characteristics of a given language, such as its morphological structure and/or productivity, Hindi and Urdu should show similar patterns of morphological priming. The alternative hypothesis proposed that if orthographic depth influences morphological processing, Hindi and Urdu should exhibit divergent patterns of morphological priming.

The results of all three experiments offered clear support for the view that morphological processing is mediated by orthographic depth. In the phonologically transparent Hindi script, superior priming by morphological as compared to form-overlapping primes emerged very early during word recognition. Crucially, this effect was constrained by prime-target SOA as well as prime presentation condition; thus, an advantage for morphological primes over unrelated controls as well as form primes was evident only when primes were heavily masked and exposed for a brief duration of 48ms. Neither unmasked primes at the 48ms SOA, nor masked primes at the 80ms SOA produced superior morphological priming of Hindi words.

Thus, despite the use of morphologically transparent prime-target pairs, the initial stage of morphological processing in Hindi, as observed in Experiments 1 to 3, resembled earlier findings on morpho-orthographic decomposition with morphologically opaque pairs in English and French (Diependaele et al., 2005; Feldman & Soltano, 1999; Longtin et al., 2003; McCormick et al., 2008; Rastle et al., 2000, 2004). A resurgence of morphological priming was also recorded in Hindi when unmasked morphological primes were exposed for 240ms (Exp. 2). Although this pattern was ascribed to morpho-semantic processing, the failure to find a similar effect in Experiment 3 leaves this interpretation in doubt. Further evidence is needed in order to establish the onset and nature of later arising morphological priming in Hindi.

In direct contrast with Hindi, morphological priming in the orthographically deep Urdu script was evident only at the longest prime-target SOA of 240ms. Interestingly, an advantage for morphological over form primes was recorded only under the masked priming procedure (Exps. 1 and 3), whereas unmasked morphological primes were found to exert an effect comparable to form-overlapping primes (Exps. 2 and 3). The superiority of morphological over form priming at the 240ms SOA in Urdu replicated and extended previous findings in several languages including English, French, German, Hebrew and Serbo-Croatian (Bentin & Feldman, 1990; Drews & Zwitserlood, 1995; Feldman & Fowler, 1987;

Feldman & Moskovljević, 1987; Feldman & Soltano, 1999; Grainger et al., 1991).

A mitigating factor in interpreting the results of the first three experiments was the absence of statistically significant priming effects in the third experiment. It was speculated that the weak priming effects might be an outcome of the greater syllable length of target stimuli, and/or the reduced form similarity between primes and targets in Experiment 3. Further testing is required in order to confirm either of these explanations. Nevertheless, the clear difference in the effect of the forward mask on Hindi vs. Urdu in the third experiment supported the existence of qualitatively different morphological processing strategies in the two languages.

Apart from furnishing support for the orthographic depth mediation view of morphological processing, Experiments 1, 2 and 3 also brought to light aspects of lexical processing in Hindi and Urdu which merit further investigation. Foremost among these is the effect of forward masking on morphological priming in both Hindi and Urdu. Adoption of the masked priming technique was initially motivated by the expectation that masked morphological priming in Hindi would resemble the pattern established previously in Indo-European languages like English and French. However, results from the three experiments showed that the effects of masking were complex and varied across

script as well as SOA. In addition to exhibiting early-onset, masked morphological priming similar to that recorded in English and French, Hindi also exhibited an apparent suppression of morphological priming under masked prime presentation at the long SOA. Further, the effect of masking on Urdu was inhibitory at the short SOA, but facilitated a morphological advantage over form primes at the long SOA.

Numerous studies have attempted to unravel the mechanisms underlying the masking effect on primed word recognition (Bodner & Masson, 1997; Forster, 1998; Forster et al., 2003; Forster & Davis, 1984; Forster, Davis, Schoknecht & Carter, 1987; Forster & Veres, 1998; Humphreys, Besner & Quinlan, 1988; Humphreys, Evett, Quinlan & Besner, 1987; Masson & Isaac, 1999; Perea & Gotor, 1997; Perea & Rosa, cf. Forster, 1998; Sereno, 1991). However, relatively few investigations incorporated masking as a variable; these studies focused on the role of the mask in mediating form priming (Forster & Veres, 1998; Humphreys et al., 1987, 1988). Results showed that masked primes that were highly similar in form facilitated recognition of targets, for example *shipping* – *skipping*; the same primes, when presented unmasked, either did not facilitate or actively inhibited target recognition.

Forster and colleagues (Forster, 1985, 1998; Forster et al., 1987; Forster & Davis, 1984; Forster & Veres, 1998) explained the effect of

masking in terms of an *entry-opening model* of word recognition, thus proposing a lexical locus for the masking effect. On this view, when a word is encountered, the lexical processor shortlists, or *opens the entries* of a set of words based on their form similarity to the given word—for example, *shipping* opens entries for *chipping*, *shipping*, *whipping*, *skipping*, *slipping*, *snipping* and *shopping*. (The rest are orthographic neighbors of *shipping* that differ from it by a single letter.) The opened entries are subsequently verified (in parallel), and all entries except the perfect match are closed; in the above example, the six entries besides *shipping* would be closed during verification. Forster's group attributed the influence of the mask to a *blocking effect*, whereby masking prevents the verification of lexical entries opened by the prime, such that when the target (*skipping*) is presented, its lexical entry is already open, reducing the effort required for its identification.

An opposing, sub-lexical explanation for the masking effect has been offered by other researchers (Bodner & Masson, 1997; Masson & Isaak, 1999). The sub-lexical view draws strength from evidence that masking induces priming among pseudowords in addition to real words (Bodner & Masson, 1997; Forster, 1985; Masson & Isaak, 1999; Sereno, 1991). In this approach, masking facilitates priming by blocking prime processing at the stage when a relatively coarse-grained orthographic (or phonological) representation of the prime has been generated; the form

similarity of the subsequently presented target enables it to benefit from the previously created, coarse-grained representation. The idea that a coarse-grained *form template* underlies masked priming is supported by evidence showing that masking leads to priming by homophones as well as pseudohomophones of primes that are semantically related to targets—for instance, both *towed* and *tode* prime *frog* (Lukatela & Turvey, 1994).

Neither the lexical nor the sub-lexical theories of masked priming offer an explanation for the superiority of transparent and opaque morphological primes over merely form-overlapping primes in the masked priming procedure (Boudelaa & Marslen-Wilson, 2001, 2004, 2005; Deutsch et al., 1998; Diependaele et al., 2005; Feldman & Soltano, 1999; Frost et al., 1997, 2000, 2005; Longtin et al., 2003; McCormick et al., 2008; Rastle et al., 2000, 2004). Indeed, Masson and Isaak (1999) specifically concluded that there was no difference in the magnitude of priming by masked morphological primes (*swore* – *swear*) and pseudoword form primes (*swire* – *swear*) in a naming task.

The current study thus represents the first attempt to systematically examine the effect of forward masking on morphological priming. Therefore, only a speculative account can be offered at present for the complex effects of masking on morphological priming in Hindi and Urdu. In brief, the effects produced by masking were as follows –

firstly, at the 48ms SOA, masked morphological primes were superior to form primes in Hindi, but not in Urdu. A second effect was that at the 240ms SOA, masking stimulated superior morphological over form priming in Urdu, but not in Hindi.

Before attempting to explain the differential effect of masking on Hindi and Urdu, a tentative explanation is offered for the early advantage of morphological over form primes under the masked priming procedure. It is proposed here that in languages such as English and Hindi, which permit early recovery of phonological information, the presence of morphological structure within a word may bias early analysis, either by favoring the opening of morphologically similar lexical entries (lexical view), or by encouraging the formation of a template of the stem or base morpheme (sub-lexical view).

Using the English analogy for the stimuli in Experiments 1 and 2, the explanation proposed above implies that the presentation of *trickster* would either open lexical entries for *trick*, *tricks*, *tricked*, *tricking* and *tricky*, or lead to the formation of a coarse-grained template of the base morpheme, *trick*. By contrast, *trickle* would open entries for *prickle*, *trinkle* and *truckle*, or support the formation of a crude template of the word itself. Thus, the subsequently presented target, *trick*, would show a greater benefit of being preceded by *trickster* than by *trickle*, since the degree of form similarity between the target and open lexical entries or

form template would be greater in the former than in the latter case.

Evidently, morphological transparency does not affect the advantage for morphologically structured primes in this account, as the benefit of both transparent and opaque morphological primes would be superior to that of form-overlapping primes.

Extending the proposal made by earlier theories that the effect of the forward mask is to block deeper processing of the prime (Bodner & Masson, 1997; Forster, 1998), the current proposal suggests that in primes exposed for longer durations, the mask does not block processing entirely, but merely hinders or *staggers* the stages of prime processing. In this view, the combination of the forward mask and longer prime exposure results in staggered prime processing, such that computation of word phonology as well as retrieval of meaning may be delayed.

Thus, the effect of the forward mask on morphological processing in Hindi may be explained thus: the early-arising (48ms) superiority of masked morphological primes may be attributed either to the activation of morphologically similar lexical entries or to the construction of a base morpheme template. On the other hand, the absence of superior morphological priming in the masked priming procedure at the long SOA (240ms) may be explained in terms of staggered morpho-semantic analysis, such that even at the 240ms SOA, priming is based only on

form similarity, and is therefore equivalent across morphological(+form) and form-only conditions.

To understand the effect of the forward mask on Urdu, it is necessary first to acknowledge that the difference in orthographic depth between Hindi and Urdu influences word recognition strategies used by readers in the two languages. As outlined in the introduction, evidence suggests that readers rely more extensively on phonological assembly in processing the more transparent Hindi script, whereas they are thought to rely on a more lexical, visually based strategy in processing Urdu (Rao, Vaid, Srinivasan & Chen, submitted; Vaid et al., 2008a).

Although the precise mechanism underlying lexical access in Urdu has not yet been established, a reasonable inference is that the printed word activates an internal visual representation of the whole word which is necessarily coarse-grained, since most vowels are omitted in written Urdu. Perhaps the configuration of the whole word is used to compute missing information, and the final, complete internal representation may provide access to word meaning as well as pronunciation; in this process, a whole word configuration that is morphologically structured may permit faster computation of missing information, and by consequence, speedier retrieval of meaning and pronunciation.

The distinct effect of the forward mask on Urdu may then be explained as follows: at the 48ms SOA, the mask blocks prime

processing at the stage when the coarse-grained, internal, visual representation of the word has been accessed, that is, before morphological structure is detected. Here, the possibility is considered that the phonologically opaque Urdu orthography precludes early identification and processing of morphophonological structure as well (Tsapkini, Kehayia & Jarema, 1999; Widmann & Morris, 2009), although this idea needs substantiation in future research.

As a result, a morphologically related Urdu target following the prime at a 48ms SOA may benefit only from overall visual similarity between prime and target, resulting in form priming. (It is acknowledged here that this explanation predicts equivalent priming by masked morphological and form primes, whereas only form-overlapping Urdu primes were effective in Experiment 1; this discrepancy is attributed to an experimental artifact.) At the 240ms SOA, the mask staggers prime processing, such that only morphologically structured primes are processed sufficiently to retrieve meaning, and thereby benefit subsequently presented targets to a greater extent than form-overlapping primes, whose facilitative effects are based purely on overall form similarity.

The above explanation thus also provides a speculative account of the early-arising form priming observed in Urdu. In discussing the results of Experiments 1 and 2, it was remarked that the incidence of

form priming in Urdu at the short SOA of 48ms conflicted with the absence of similar effects in the highly similar orthographies of Arabic and Hebrew (Boudelaa & Marslen-Wilson, 2005; Frost et al., 1997, 2005). It was suggested that this difference may arise from the different morphological typology of Urdu as opposed to Semitic languages. The deviance of Urdu from Arabic and Hebrew was further supported by evidence showing that at longer prime-target SOAs, Urdu failed to exhibit significant form-based facilitation (Rao et al., submitted), in contrast with the finding that form primes facilitated Hebrew word recognition at intervals as long as 3s (Bentin, 1989).

An additional phenomenon highlighted by the present results was the consistent finding that Hindi and Urdu words were named significantly more slowly at the 240ms SOA than at 48ms; Experiment 1 additionally recorded a significant cost for the 240ms SOA compared to the 80ms SOA. It was hypothesized in earlier sections that this effect may have arisen from a competitive inhibition exercised by primes over targets, with the effect becoming evident only after sufficient processing of the prime, that is, at the longest SOA of 240ms. Such an explanation predicts that the inhibitory effect of primes should dissipate if prime processing is allowed to reach completion, as for example in a delayed naming task.

Taken together, the experiments comprising the first part of this research offer a compelling argument for the hypothesis that orthographic depth influences morphological processing strategy. Highly proficient bicultural readers of Hindi and Urdu exhibited distinct patterns of morphological priming when tested in the two languages, even though the same words were presented for recognition in both. Masked morphological primes were effective at a very early prime-target SOA of 48ms in the shallow Hindi orthography, whereas phonologically opaque Urdu orthography exhibited a morphological advantage only at the long SOA (240ms). Experiments 1, 2 and 3 also provided clear evidence that forward masking plays an important role in the initial as well as later stages of primed word recognition in Hindi and Urdu.

HEMISPHERIC ASYMMETRY IN MORPHOLOGICAL PROCESSING

As stated in the introduction, an additional aim of this research was to explore the role of orthographic depth in mediating hemispheric asymmetry in morphological processing. Experiments 4 and 5 were designed to test a claim that the right hemisphere (RH) is more sensitive than the left hemisphere (LH) to morphological structure. A competing claim is that orthographic depth differences underlie observed functional asymmetries in processing morphology. To provide a context for these arguments, a brief overview of relevant laterality research is presented first.

The issue of the relative contribution of the left and the right cerebral hemisphere to language processing has interested researchers for over a century, and continues to be researched intensively. The issue is complex since hemispheric differences are known to be influenced by several factors, including input (or stimulus) characteristics, task demands, and individual differences in language experience.

Input characteristics include such variables as presentation modality (auditory vs. visual), properties affecting spoken language (phonology, stress patterns, tone, etc.), and properties affecting written language (visuospatial complexity, script directionality, and orthographic depth). Input characteristics also include the unit of language studied

(single words, phrases, sentences, discourse). Task demands refer to the type of component processing called for by the task (orthographic, phonological, semantic, or morphological) as well as the other types of judgments required (that is, pragmatic vs. semantic/syntactic). The third category of variables influencing patterns of lateralization includes variables such as linguistic background (monolingual, bilingual or multilingual), literacy level and, in the case of bi- and multilingual populations, additional factors such as proficiency, age of acquisition and pattern of use of each language, as well the non-linguistic factors of handedness or gender. The picture is further complicated by interactions among the above variables (e.g., Obler, Zatorre, Galloway, & Vaid, 1982; Hull & Vaid, 2006).

A detailed review of the influence of each of the above variables on the lateralization of language processing is outside the purview of this dissertation. The research presented here is concerned specifically with hemispheric asymmetry in processing morphological features of visually presented, single words, and with the influence of orthographic depth in moderating hemispheric dominance. To that end, the description below focuses on the role of the left vs. right hemispheres in visual word recognition, followed by a summary of research on the influence of orthographic depth on the left-right processing bias. Findings on the

hemispheric bias in morphological processing are then presented, leading to the competing predictions motivating this study.

Left Hemisphere Dominance in Visual Word Recognition

Behavioral experiments on the lateralization of word recognition have traditionally used the *visual hemifield* paradigm, in which stimuli are very briefly presented either in the left or the right half of the reader's field of vision—this procedure relies on a property of vision whereby information from the two halves of the visual field are initially conveyed to the contralateral (opposite) cerebral hemispheres, and hence only available to that hemisphere for the first 150ms to 200ms of processing. Thus, asymmetries in responses to stimuli exposed for less than 200ms in the right vs. left visual hemifields (henceforth simply *visual fields*) are understood to reflect underlying differences in the information-processing ability of the left vs. right cerebral hemispheres respectively.

Studies on a variety of Western and Eastern languages, including alphabetic and non-alphabetic writing systems such as Chinese, English, Finnish, French, German, Italian and Japanese have repeatedly confirmed that the left hemisphere (LH) dominates visual word recognition, that is to say, the LH is vastly more efficient than the right hemisphere (RH) at identifying visually presented words (Hagoort,

Indefrey, Brown, Herzog, Steinmetz & Seitz, 1999; Hellige, 2001; Hellige & Yamauchi, 1999; Kuo et al., 2001; Mainy et al., 2007; Proverbio, Vecchi & Zani, 2006; Sakurai et al., 1992; Stief & Schweinberger, 1999; Tarkiainen, Helenius, Hansen, Cornelissen & Salmelin, 1999).

A substantial volume of research on normal as well as clinical populations has addressed the relative ability of the left and right hemispheres in processing form level (phonology and orthography) and semantic features of written words (Baynes, Tramo & Gazzaniga, 1992; Beeman & Chiarello, 1998; Bub & Lewine, 1988; Chiarello, 1985, 1991; Crossman & Polich, 1988; Ellis, 2004; Ellis, Young & Anderson, 1988; Faust & Chiarello, 1998; Gibson, Dimond & Gazzaniga, 1972; Lavidor & Ellis, 2003; Shillcock & McDonald, 2005; Simpson & Burgess, 1985; Whitney, 2004; Yochim, Kender, Abeare, Gustafson & Whitman, 2005; Zaidel, 1998). Cumulatively, the evidence indicates that the right hemisphere (RH) has only a limited capacity for lexical processing on the basis of whole-word visual form, with no phonological processing ability; this dichotomy is illustrated nicely by Lavidor and Ellis' (2003) finding that word recognition in the left but not the right hemisphere benefited from cues that were phonologically but not visually similar to targets (e.g., *FAWNED* – *fond*), whereas the right hemisphere showed facilitation by primes that were similar in visual form, despite their phonological dissimilarity to targets (e.g., *COUGH* – *couch*).

Orthographic Depth and Right Hemisphere Involvement

While the bulk of evidence points to a uniform left hemisphere advantage in word recognition, investigators have furnished proof that in languages with deep orthographies, such as Chinese, Hebrew, Japanese, Persian and Urdu, the degree of hemispheric asymmetry in lexical processing may be reduced.

A notable study by Melamed and Zaidel (1993) examined lateralized word naming and lexical decision among readers of Farsi (Persian). The Farsi script is descended from Arabic, and preserves the consonantal spelling convention, and by implication, the phonological opacity of Arabic.

The authors found no advantage in participants' response speed or accuracy to words presented to the right visual field/left hemisphere (RVF/LH) in either naming or lexical decision tasks. In comparison, a second group of readers tested in their native English exhibited a robust LH advantage in the lexical decision task, as well as in word naming accuracy. Melamed and Zaidel argued that since neither naming nor lexical decisions in Farsi showed an RVF/LH advantage, the findings supported greater RH involvement during word recognition in Farsi than in English.

Studies conducted on Chinese and Japanese orthographies have similarly demonstrated attenuated left vs. right asymmetry in word

recognition. Leong, Wong, Wong and Hiscock (1985) demonstrated that the LH bias in processing Chinese depended on the nature of the task. In their study, readers of Chinese were asked to make three types of judgments—one experiment required participants to judge whether each stimulus configuration represented a legal Chinese character (with non-legal characters being laterally inverted images of actual characters), a second presented pairs of characters for homophone judgment, while a third required readers to perform semantic categorization by judging if characters (words) were members of a specific category.

Leong et al.'s results showed a clear RVF/LH advantage for experiments 2 (homophone judgment) and 3 (semantic categorization), whereas experiment 1 (differentiating real from false Chinese characters) yielded equally efficient performance in trials presented to the right and left visual fields. Yang (1999) replicated the results of Leong et al. (1985) by finding an RVF/LH advantage for homophone judgments in Chinese, but reported a significant left visual field/right hemisphere (LVF/RH) advantage in judging orthographic similarity.

Studies of Japanese orthography have similarly demonstrated that processing of phonologically transparent Kana characters revealed uniform LH dominance, whereas phonologically opaque Kanji characters elicited varying patterns of hemispheric asymmetry, depending on task demands (Sasanuma, Itoh, Kobayashi & Mori, 1977; 1980). Further,

Japanese readers' performance on reading-related tasks showed different patterns of interference depending on the type of distracter used. When distracters were presented in the RVF/LH of Japanese readers, Kana distracters were more disruptive, whereas in the LVF/RH, Kanji characters exercised a greater interference effect (Hatta, Katoh & Aitani, 1983; Yamaguchi, Toyoda, Xu, Kobayashi & Henik, 2002).

Evidence further suggests that LH dominance in visual word processing may arise in part due to its ability to process letters in parallel, whereas the RH is limited to sequential processing—for example, readers of English, when asked to identify unilaterally presented letter-strings made different types of errors on stimuli presented to the right vs. left visual fields. Errors in the RVF/LH were uniformly spread across letters at different positions in the string, whereas LVF/RH errors exhibited a clear *serial position effect*—that is, the fewest errors occurred on the first letter, more on the second, and the most errors on the last letter of letter trigrams. By contrast, readers of orthographically deep languages like Hebrew, Japanese and Urdu showed similar patterns of letter-identification errors in the RVF and LVF, suggesting that the right hemisphere in these readers is also capable of processing letters in parallel (Adamson & Hellige, 2006; Eviatar, 1999; Hellige & Yamauchi, 1999).

Left Hemisphere Specialization for Morphological Processing

Relatively few studies have investigated hemispheric specialization for processing morphological information among normal readers. A major challenge facing researchers in this area is the disentanglement of morphology from phonological, orthographic and semantic features of the stimuli. Investigators studying hemispheric specialization for morphological processing have attempted to solve the problem in different ways (Burgess & Skodis, 1993; Eviatar & Ibrahim, 2007; Koenig, Wetzel & Caramazza, 1992).

Burgess and Skodis (1993) compared lexical decision speed and accuracy to *morphologically ambiguous* and *unambiguous* verbs using the visual hemifield technique; ambiguous verbs belonged to two syntactic categories (e.g., *chased* and *parked* serve as simple past tense as well as past participle forms of the verbs), while unambiguous verbs were members of a single category (e.g., *stolen*, *fallen*). It was hypothesized that the ability to process morphological information would result in faster responses to ambiguous verbs, since their multiple category membership would lead to stronger activation.

Results showed significantly faster responses to ambiguous than unambiguous verbs only for items presented to the VF/LH. The two types of verbs elicited similar response latencies in LVF/RH trials, leading Burgess and Skodis to conclude that the left hemisphere enjoys

an advantage over the right hemisphere in processing morphological information.

Koenig et al. (1992) studied hemispheric specialization among readers of French, using a lateralized (visual hemifield) lexical decision task. In their study, pseudowords were either morphologically decomposable, that is, formed from real roots and affixes (analogous to *rided* and *findment*) or non-decomposable (*mided*, *lindment*). Their results confirmed the predicted LH advantage in word recognition, with faster and more accurate responses overall to both words and pseudowords. However, the pseudowords in Koenig et al.'s study revealed a significant difference between left and right hemispheres. The LH was more accurate than the RH at rejecting pseudowords that were morphologically non-decomposable (e.g., *mided*), but the LH was slow at rejecting decomposable pseudowords (e.g., *rided*), being reduced to the same speed as the RH for items in this category. This result indicated that processing in the left, but not the right hemisphere was sensitive to the morphological structure.

Neuroimaging studies have similarly attempted to dissociate brain regions involved in morphological processing from those involved in processing other dimensions of words. Some studies reported evidence of activation exclusive to morphological processing (Bick, Goelman & Frost, 2008; Gold & Rastle, 2007), whereas others found no areas

dedicated to morphology (Devlin, Jamison, Matthews & Gonnerman, 2004). Despite mixed findings on the exclusiveness of ‘morphological’ sites in the brain, studies on morphological processing invariably report predominantly left hemisphere activation across several languages, including English, Finnish, German, Italian and Spanish (Beretta et al., 2003; Bornkessel, Zysset, Friederici, von Cramon & Schlesewsky, 2005; Bozic, Marslen-Wilson, Stamatakis, Davis & Tyler, 2007; Cappelletti, Fregni, Shapiro, Pascual-Leone & Caramazza, 2008; Hernandez, Kotz, Hofmann, Valentin, Dapretto & Bookheimer, 2004; Laine, Rinne, Krause, Teräs & Sipilä, 1999; Lehtonen, Vorobyev, Hugdahl, Tuokkola & Laine, 2006; Marangolo, Piras, Galati & Burani, 2006).

These findings have been supplemented by clinical evidence showing that damage to LH areas known to be involved in morphological processing led to impairment in tasks requiring morphological judgment, as well as to reduced sensitivity to morphological information (Badecker & Caramazza, 1991; Caramazza & Hillis, 1991; Hagiwara, Ito, Sugioka, Kawamura & Shiota, 1999; Miceli & Caramazza, 1988; Tyler, Demornay-Davies, Anokhina, Longworth, Randall & Marslen-Wilson, 2002; Tyler, Marslen-Wilson & Stamatakis, 2005).

For instance, Caramazza and Hillis (1991) reported that damage to the left Inferior Frontal Gyrus (LIFG) disrupted morphological judgment, leading patients to use incorrect inflections and derivations (e.g.,

darkness in place of *darken*), while Tyler et al. (2005) found LH damage to result in processing dissociations, such as priming of words in specific morphological categories but not in others, for example, priming limited to irregularly inflected verbs (*began* – *begin*) or for regular verbs only (*turned* – *turn*).

Right Hemisphere Capacity for Morphological Processing

As outlined above, the vast majority of research suggests that the left hemisphere is predominantly responsible for morphological processing. Nonetheless, a small number of studies indicate that the right hemisphere in readers of certain languages may be capable of analyzing morphological information. Eviatar and Ibrahim (2007) compared morphological processing in English, Arabic and Hebrew, testing readers on lexical decision tasks in their native language. Corroborating earlier findings in English and French (Burgess & Skodis, 1993; Koenig et al., 1992), Eviatar and Ibrahim found the expected LH advantage for morphological processing among English readers—responses to morphologically simple words and pseudowords were significantly faster and more accurate than those to complex words as well as pseudowords in RVF/LH trials, whereas the LVF/RH evinced no sensitivity to morphological complexity.

Readers of Arabic as well as Hebrew in Eviatar and Ibrahim's study exhibited overall LH superiority in lexical decision, but responses to pseudowords revealed a different pattern—in both RVF as well as LVF trials, simple pseudowords were rejected more accurately than were morphologically decomposable pseudowords, that is, pseudowords containing real root morphemes. Among Arabic readers, there was no visual field difference in latencies to reject morphologically decomposable pseudowords. The authors attributed this pattern to a greater sensitivity of the RH to morphological structure among Arabic and Hebrew readers.

Eviatar and Ibrahim (2007) proposed that an increased RH sensitivity to morphological processing is due to the non-concatenative morphology of Arabic and Hebrew. In this view, extraction of the consonantal root that is the central feature of Arabic and Hebrew morphology may be associated with right hemisphere processing.

A different explanation for RH involvement in morphological processing was put forth by Laine and Koivisto (1998). In their study, readers of Finnish evinced the typical LH advantage in morphological processing: lexical decisions were faster to morphologically simple (monomorphemic) vs. complex words in the RVF. However, complex pseudowords elicited significantly more errors than simple (non-decomposable) pseudowords even in LVF presentation, leading the

authors to argue that the RH develops a greater ability for morphological processing in languages with rich morphological structure. Finnish is heavily inflected and makes extensive use of derivations, with most words belonging to large morphological families—as an extreme instance, *työ* (*work*) has a family size of 7000 (Moscoso del Prado Martin, Bertram, Häikiö, Schreuder & Baayen, 2004).

DOES ORTHOGRAPHIC DEPTH MODULATE MORPHOLOGICAL PROCESSING ASYMMETRY IN HINDI AND URDU?

Available evidence on hemispheric asymmetry in language-related tasks suggests that both Hindi and Urdu exhibit the widely documented right visual field/left hemisphere advantage (Adamson & Hellige, 2006; Vaid, 1988). Vaid (1988) compared hemispheric asymmetry in identifying the language – Hindi vs. Urdu – in which words were presented, using a lateralized language adaptation of the Stroop task where the words *Hindi* and *Urdu* were each presented in Hindi and Urdu script. The results revealed an overall RVF advantage in identifying the language of the words, in native Hindi and native Urdu readers alike.

Adamson and Hellige (2006) likewise recorded a consistent RVF superiority in Urdu letter identification among Urdu-English bilingual readers; nonetheless, their results uncovered a qualitative difference in LVF/RH errors between Urdu and English—participants showed no effect of serial position in LVF/RH trials while identifying the letters comprising Urdu letter-strings, whereas English strings elicited a pronounced serial position effect.

The current study asked whether hemispheric asymmetry in morphological processing is affected by the orthographic depth of the writing system. This hypothesis was tested in two experiments

comparing lateralized morphological priming in Hindi vs. Urdu. As stated in the introduction, Hindi and Urdu share a morphophonological identity, but are distinct in orthographic representation; Hindi script is highly phonologically transparent, whereas Urdu is a deep orthography descended from Arabic. The experiments presented in the following section tested the prediction that differences in orthographic depth between Hindi and Urdu would result in divergent patterns of asymmetry in morphological priming.

Experiments 4 and 5 tested biliterate, bicultural Hindi/Urdu readers on lateralized word naming tasks. Participants named words presented either in the right or left visual field in a long-term priming procedure; that is, readers were asked to name lists of words containing morphologically related prime-target pairs, with the prime and target in each pair separated by a fixed lag of 10 items. Similarly to previous experiments, morphological priming effects were evaluated against responses to control as well as form-primed targets.

As per extant views of morphological processing, the common morphology of Hindi and Urdu should result in identical patterns of hemispheric asymmetry in morphological priming. According to Eviatar and Ibrahim (2007), RH involvement stems from non-concatenative morphology. As described earlier, Hindi and Urdu are predominantly concatenative, but include some non-concatenative elements. Extending

Eviatar and Ibrahim's view, morphological priming in both Hindi and Urdu might be expected to be confined exclusively to the right visual field (left hemisphere), or it might extend to the left visual field (right hemisphere).

The position taken by Laine and Koivisto (1998), on the other hand, attributes RH morphological sensitivity to the richness of morphological productivity in a given language. The section on Hindi-Urdu morphology contrasted the relative morphological richness of these languages with the sparseness of English morphology. Once again, the morphological productivity view of Laine and Koivisto admits both possibilities, that Hindi and Urdu might show an exclusive LH bias, or they might both show attenuated asymmetry in morphological priming.

The important point to note is that both of these views predict an equivalent pattern of hemispheric asymmetry for morphological processing in Hindi and Urdu. By contrast, an orthographic depth-based account would predict differences in patterns of hemispheric asymmetry in Hindi vs. Urdu. Specifically, a stronger RVF superiority should characterize Hindi than Urdu, reflecting the greater transparency of Hindi script.

A similar prediction of divergent patterns in hemispheric asymmetry might also be predicted on the basis of the opposite script directionality of Hindi vs. Urdu—Hindi is written from left to right,

whereas Urdu preserves the right-to-left directionality of its model script, Arabic. Previous research indicates that in scripts written from right to left, the effect of *reading habit* influences performance on non-linguistic tasks involving visual attention and scanning, such as drawing and aesthetic judgments of scenes and faces. Investigators have shown that readers of languages such as Arabic, Hebrew, Persian and Urdu exhibit either a right-to-left bias or no bias in visual attention when compared to the pronounced left-to-right bias documented among readers of English, Hindi and other left-to-right languages (Christman & Pinger, 1997; Dennis & Raskin, 1960; Eviatar, 1997; Heath, Mahmassani, Rouhana & Nassif, 2005; Maass & Russo, 2003; Nachshon, 1985; Nachshon, Argaman & Luria, 1999; Vaid, 1995; Vaid & Singh, 1989).

If reading habits also exert an influence in the processing of laterally presented verbal stimuli, one would expect a left field advantage for Urdu word recognition but a right field advantage for Hindi word recognition (assuming unilateral presentation conditions). However, unlike the strong evidence for script directionality effects in nonlinguistic processing, there is little empirical indication that script directionality is the primary variable underlying asymmetries in word recognition.

Adamson and Hellige (2006) showed a right visual field advantage in Urdu letter recognition in native readers of Urdu; similarly, Vaid

(1988) showed a right field advantage in Urdu word identification. In addition, research on right-to-left scripts such as Arabic and Hebrew similarly argues for the dominant role of the left hemisphere during lexical processing (Eviatar, 1999; Eviatar, Ibrahim & Ganayim, 2004). Therefore, it was considered that a potential attenuation in morphological priming asymmetry in Urdu compared to Hindi might be reasonably attributed to the greater orthographic depth of Urdu rather than to its reversed directionality.

EXPERIMENT 4: LATERALIZED LONG-TERM MORPHOLOGICAL PRIMING OF HINDI AND URDU MONOSYLLABIC WORDS

The present study sought to examine whether patterns of hemispheric asymmetry for morphologically related prime-target pairs would be equivalent or divergent in Hindi vs. Urdu. Participants were to name Hindi and Urdu words presented unilaterally, that is, words presented randomly in either the left or the right visual field. Stimuli were one-syllable targets and two-syllable primes separated by fillers, with the prime-target interval maintained at lag 10. Primes belonged to one of three conditions, morphological, form and control (unrelated). Facilitation by morphological as well as form-related primes was gauged with respect to the unrelated condition, and the morphological nature of observed effects was further verified relative to form priming.

In the absence of previous data on hemispheric asymmetry in word identification speed and accuracy in Hindi and Urdu, and specifically to address the issue of script directionality effects, filler words in the current study were analyzed separately to provide a measure of baseline hemispheric asymmetry for word naming in Hindi and Urdu. Accordingly, the results section provides a summary of the analysis based on the filler data before presenting the analysis based on the critical prime-target words.

Method

Participants. Twenty-six proficient bicultural readers of Hindi and Urdu were recruited from a university in Allahabad, in northern India, and included 19 males and 7 females, ranging in age from 19 to 47 years ($M = 27$). Participants used Hindi and Urdu on a daily basis. Hindi was the medium of instruction of most participants, and most had learned Urdu in elementary school and beyond. Further, all participants in the present study had studied Urdu at university level. On a 7-point scale, participants rated themselves as highly proficient in reading in Hindi ($M = 6.8$, $SD = 0.4$) and in Urdu ($M = 6.7$, $SD = 0.6$). Participants were paid per hour of involvement in the study.

Design and Materials. The experiment used a 2 (Script: Hindi, Urdu) by 3 (Prime Type: morphological, form, control) by 2 (Visual Field: right, left) within-subjects factorial design. Stimuli were the same set of 78 targets paired with morphological, form and unrelated primes as in Experiment 1 (refer to Table 1 for examples), with the modification that all words were presented in white font on a black background. The set of 96 filler words (48 words each of one and two syllables) was used to space experimental prime-target pairs appropriately.

Procedure. E-Prime experimental software (Psychological Software Tools Inc., 2003) was used to present stimuli lateralized to participants' right or left visual fields in a speeded naming task. Viewing

distance was held constant at 42cm with the aid of a chin-rest aligned with the screen center, such that the inner edge of stimuli subtended a visual angle of 2° , while the viewing angle of the outer edge varied from 3.3° to 5.5° . In each trial, a cross-hair centered on the screen allowed participants to fixate briefly (300ms) before flickering to signal the onset of the word displayed for 160ms in either the right or left visual field. A blank screen replaced the stimulus and lasted until the onset of the participant's response triggered a voice key (Serial Response Box, Psychological Software Tools Inc.) and enabled logging of response latency in milliseconds. Naming accuracy was manually coded later based on digital recordings of experiment sessions (Sony® Digital Voice Recorder, ICD P-320). ISIs lasted 1000ms.

Participants viewed half the stimuli in Hindi and the remainder in Urdu, in separate blocks, with language order counterbalanced. Each block consisted of 126 trials, including 78 experimental items and 24 filler pairs; experimental trials included 13 prime-target pairs each from the morphological, form and control conditions. Blocks were subdivided into three sets of 42 trials each. Order of items was fixed within sets, in order to maintain a constant lag of nine items between primes and their respective targets, but order of sets within a block was randomized. Primes and targets were lateralized to the same visual field.

Multiple versions of the experiment were created to ensure that each target was presented once each in the right and left visual fields in Hindi as well as Urdu, and to further ensure that each target was preceded once per combination of Script and Visual Field by its morphological, form and control primes. The different versions were counterbalanced across participants, so that a reader saw a given item, whether prime or target, only once.

Results

Visual Field Asymmetries for Hindi and Urdu Filler Words.

Participants' mean accuracy and reaction time in filler trials were computed and analyzed in separate 2 (Script: Hindi, Urdu) by 2 (Syllable Length: one, two) by 2 (Visual Field: right, left) within-subjects ANOVAs. Refer to Table 6 for participants' mean naming latency and accuracy to fillers. Incorrect responses and outliers (latencies below 250ms and above 1750ms) were eliminated from the analyses; outliers accounted for 1.2% each of Hindi and Urdu data-points.

The accuracy ANOVA yielded main effects of Script [$F(1, 25) = 12.32, p < .05, MSE = 0.012, \eta^2 = .33$] and Syllable Length [$F(1, 25) = 24.38, p < .05, MSE = 0.010, \eta^2 = .49$], which were modified in a two-way interaction, $F(1, 25) = 7.18, p < .05, MSE = 0.008, \eta^2 = .22$. Simple effects ANOVA showed the interaction to arise from a significant

difference in naming accuracy between one- and two-syllable Urdu words [$F(1, 50) = 14.96, p < .05, MSE = 0.009, \eta^2 = .23$], although no difference was found in Hindi ($p > .10$). No effect of Visual Field emerged.

RT ANOVA revealed main effects of all three variables—Script [$F(1, 25) = 7.26, p < .05, MSE = 8679.15, \eta^2 = .23$], Syllable Length [$F(1, 25) = 45.72, p < .05, MSE = 4530.25, \eta^2 = .65$] and Visual Field [$F(1, 25) = 18.18, p < .05, MSE = 1964.21, \eta^2 = .42$]. These effects were modified by a Script \times Visual Field interaction, $F(1, 25) = 12.95, p < .05, MSE = 1358.03, \eta^2 = .32$, and further by a three-way interaction, $F(1, 25) =$

Table 6

Exp. 4: Participants' naming latency (RT) and proportion accuracy in right vs. left visual field (RVF/LH vs. LVF/RH) presentations of Hindi vs. Urdu filler words ($n = 26$)

	Hindi		Urdu		
1-Syllable	Mean RT	Accuracy	Mean RT	Accuracy	
	RVF/LH	492 (15) ¹	0.95 (0.01)	512 (17)	0.96 (0.02)
	LVF/RH	515 (18)	0.97 (0.01)	554 (21)	0.92 (0.01)
2-Syllable					
	RVF/LH	529 (19)	0.94 (0.02)	615 (25)	0.85 (0.03)
	LVF/RH	594 (22)	0.91 (0.02)	589 (23)	0.83 (0.03)

¹Standard error values italicized in parentheses.

27.98, $p < .05$, $MSE = 1415.84$, $\eta^2 = .53$. Simple effects ANOVA of the two-way interaction yielded a consistent RVF advantage in Hindi, $F(1, 50) = 15.56$, $p < .05$, $MSE = 1661.12$, $\eta^2 = .24$, but no visual field difference in Urdu ($p > .10$). Further contrasts revealed that the three-way interaction arose from opposing patterns of visual field asymmetry in Urdu—one-syllable Urdu words showed a right field advantage [$F(1, 100) = 14.03$, $p < .05$, $MSE = 1612.57$, $\eta^2 = .12$], while two-syllable words showed a left field advantage [$F(1, 100) = 5.48$, $p < .05$, $MSE = 1612.57$, $\eta^2 = .05$].

Visual Field Asymmetries for Hindi and Urdu Targets. Outlier trimming (latencies below 250ms and above 1500ms) led to removal of 1.3% of Hindi and 0.9% of Urdu data. Mean response accuracy and latency were calculated for morphological, form and control conditions in each language, revealing greater accuracy and faster responses in Hindi (98.4%, 479ms) compared to Urdu (95.4%, 525ms). Refer to Table 7 for mean condition-wise accuracy and latency. Participants⁸ responses were analyzed in separate 2 (Script) \times 3 (Prime Type) \times 2 (Visual Field) within- subjects ANOVAs of naming accuracy and latency. Incorrect trials and outlier response latencies (RTs shorter than 250ms and longer than 1500ms) were removed prior to RT analyses.

⁸ The results and discussion reported here are limited to analyses of participant-wise means. The unavailability of a larger sample, combined with the large number of cells in the within-subject factorial design ($2 \times 3 \times 2 = 12$) prevented item analyses, as certain conditions remained unrepresented for certain items.

The accuracy analysis yielded main effects of Script [$F(1, 25) = 13.42, p < .05, MSE = 0.005, \eta^2 = .35$] and Prime Type [$F(2, 50) = 3.13, p = .05, MSE = 0.004, \eta^2 = .11$], which were qualified by a two-way interaction, $F(2, 50) = 4.63, p < .05, MSE = 0.005, \eta^2 = .16$. The interaction was further analyzed in simple effects ANOVA, revealing a significant influence of Prime Type on Urdu [$F(2, 100) = 3.62, p < .05, MSE = 0.004, \eta^2 = .07$] but not on Hindi naming accuracy ($p > .10$). Contrasts were computed on the Urdu data to examine differences among priming conditions (family-wise $\alpha = .004$), showing marginally superior accuracy relative to control in morphological [$F(1, 100) = 4.52, p < .04, MSE = 0.004, \eta^2 = .04$] as well as form conditions [$F(1, 100) = 6.10, p < .02, MSE = 0.004, \eta^2 = .06$], but no difference between them.

ANOVA of reaction time data revealed effects of Script [$F(1, 25) = 30.54, p < .05, MSE = 5432.55, \eta^2 = .55$], Prime Type [$F(2, 50) = 5.53, p < .05, MSE = 1954.49, \eta^2 = .18$] and Visual Field [$F(1, 25) = 35.86, p < .05, MSE = 1620.84, \eta^2 = .59$], as well as a marginal three-way interaction, $F(2, 50) = 2.94, p = .06, MSE = 1512.46, \eta^2 = .11$. In order to verify the pattern of hemispheric asymmetry established with filler items, the effect of Visual Field was further subjected to planned comparisons (family-wise $\alpha = .02$), revealing a significant advantage for RVF trials in

both Hindi [$F(1, 50) = 6.00, p < .02, MSE = 1485.94, \eta^2 = .11$] and Urdu [$F(1, 50) = 7.06, p < .02, MSE = 1485.94, \eta^2 = .12$].

The near-significant three-way interaction was examined further in simple contrasts of Prime Type per Script and Visual Field. These tests showed that in RVF trials, Hindi exhibited no priming relative to control in either morphological or form conditions ($ps > .10$). In LVF trials, Hindi showed an advantage for the form condition over the control, $F(1, 200) = 8.53, p < .05, MSE = 1659.17, \eta^2 = .04$. The morphological condition did not differ significantly from control ($p > .05$), and no difference emerged between form and morphological conditions in either visual field (both $ps > .05$).

By contrast, Urdu exhibited no advantage for either morphological or form conditions relative to the control condition in RVF trials (both $ps > .05$). However, the morphological condition produced significantly faster responses compared to the control condition in LVF trials, $F(1, 200) = 6.70, p < .02, MSE = 1659.17, \eta^2 = .03$; further, the morphological condition exhibited a significant advantage over the form condition in the LVF, $F(1, 200) = 6.37, p < .02, MSE = 1659.17, \eta^2 = .03$. No difference between the form and control conditions was found in either visual field in Urdu ($ps > .10$). See Figure 8 for a graph of visual field asymmetry in Hindi vs. Urdu priming patterns.

Table 7

Exp. 4: Participants' word naming latency (RT) and proportion accuracy in right vs. left visual field (RVF/LH vs. LVF/RH) presentations of Hindi vs. Urdu targets cued by morphological (Morph), form-overlapping (Form) and unrelated (Control) primes (n = 26)

Visual Field	Prime	Hindi		Urdu	
	Type	Mean RT	Accuracy	Mean RT	Accuracy
RVF/LH	Morph	458 (15) ¹	0.99 (0.01)	501 (17)	0.96 (0.01)
	Form	469 (15)	0.98 (0.01)	509 (15)	0.99 (0.02)
	Control	470 (15)	0.98 (0.01)	522 (18)	0.93 (0.02)
LVF/RH	Morph	490 (17)	0.98 (0.01)	520 (19)	0.97 (0.02)
	Form	476 (12)	0.97 (0.01)	548 (16)	0.96 (0.01)
	Control	509 (16)	0.99 (0.01)	549 (22)	0.92 (0.02)

¹Standard error values italicized in parentheses .

Discussion

Experiment 4 assessed long-term, lateralized morphological priming in Hindi and Urdu with a view to establishing the influence of orthographic depth on hemispheric asymmetry in morphological priming. Participants named words presented in Hindi and Urdu, in which morphological prime-target pairs were separated by filler stimuli as well

as by form-related and unrelated controls. All stimuli were presented in either the right or the left visual field of participants, with primes and corresponding targets lateralized to the same visual field.

Preliminary analyses of filler words revealed significantly higher accuracy and faster responses in Hindi than in Urdu, thereby replicating earlier observations with centrally presented words (Exps. 1 – 3 in the present research; Rao et al., under review). Additionally, Hindi filler words presented to the RVF were named faster than those presented to the LVF, whereas Urdu fillers revealed an interaction of visual field with syllable length—one-syllable Urdu words were named faster in RVF presentations, whereas two-syllable words elicited faster responses in the LVF.

The right visual field/left hemisphere advantage in processing Hindi as well as Urdu words thus confirmed and extended previous findings (Adamson & Hellige, 2006; Vaid, 1988). However, the faster responses to two-syllable Urdu fillers in LVF trials may be interpreted in two ways. One possibility is that the relative opacity of Urdu orthography contributed to an attenuated LH advantage in Urdu word recognition, although the possibility must also be acknowledged that the right-to-left directionality of Urdu script might underlie the observed reduction in the RVF advantage in Urdu.

Priming data in the above experiment corroborated the advantage of Hindi over Urdu naming accuracy ($MD = 3\%$), as well as an RVF advantage in response latencies to Hindi and Urdu words of one syllable. A near significant three-way interaction in the RT data of Script, Prime Type and Visual Field ($p = .06$) further revealed significant differences in priming asymmetry between Hindi and Urdu.

Contrary to expectation, Hindi exhibited no advantage for morphologically primed targets in the RVF. A significant advantage for form over control conditions emerged in the LVF ($MD = 33\text{ms}$). As distinct from Hindi, Urdu exhibited no advantage for the form condition in either visual field, whereas LVF trials revealed the morphological condition to be superior to both control ($MD = 29\text{ms}$) and form conditions ($MD = 28\text{ms}$).

The form priming recorded for Hindi words presented in the LVF (RH) accorded with earlier evidence of right hemisphere form priming among readers of English and French (Chiarello, 1985; Crossman & Polich, 1988; Lavidor & Ellis, 2003). The lack of priming in RVF trials in Hindi was interpreted as a ceiling effect on performance, as evidenced by extremely high accuracy (99%) even to control targets in the RVF.

As opposed to Hindi, Urdu exhibited a morphological advantage over unrelated as well as form conditions, although the effect was confined to LVF/RH presentations. In the absence of a clear priming

bias in Hindi, the pattern in Urdu did not provide conclusive evidence favoring the orthographic depth mediation view of morphological processing asymmetry. Nevertheless, the pattern of an LVF/RH bias in Urdu morphological priming underscored the possibility that greater orthographic depth may result in a reduced LH bias in processing visually presented words.

The next experiment was conducted to verify and extend the current findings. Summarizing the results so far, Experiment 4 documented a clear right field advantage in identifying one-syllable words in both Hindi and Urdu. Additionally, a left field bias was found in responses to two-syllable Urdu fillers as well as to morphologically primed targets, suggesting that orthographic depth may mediate hemispheric asymmetry in Urdu word recognition, including morphological processing strategy. Finally, an advantage for Hindi form-overlapping targets in the LVF extends previous findings in other languages showing right hemisphere form priming.

In Experiment 5, the aim was to establish significant morphological priming in Hindi. To overcome possible ceiling effects, longer targets of two and three syllables were used. Additionally, Experiment 5 aimed to replicate the LVF advantage in Urdu morphological priming. A third goal of the experiment was to verify the

baseline pattern of visual field asymmetry in Hindi and Urdu word recognition.

EXPERIMENT 5: LATERALIZED LONG-TERM MORPHOLOGICAL PRIMING OF HINDI AND URDU POLYSYLLABIC WORDS

This experiment sought to examine differences between Hindi and Urdu in the hemispheric processing of morphological information. Similarly to Experiment 4, participants named Hindi and Urdu words presented either in the left or right visual fields, including primes and targets that were morphologically related, similar only in form, or unrelated, and separated by fillers. We expected that Experiment 5 would replicate the previous experiment by demonstrating morphological priming for LVF-presented words in Urdu. In addition, the current experiment was expected to furnish evidence of long-term morphological priming in one or both visual fields in Hindi.

Method

Participants, Design and Materials. The same group of 26 readers was tested as in Experiment 4. A 2 (Script: Hindi, Urdu) by 3 (Prime Type: morphological, form, control) by 2 (Visual Field: right, left) within-subjects factorial design was used. Stimuli were the 48 tetrads used in Experiment 2, and included 48 targets (43 two-syllable and 5 three-syllable words) matched with three primes each (see Table 4 for an example). Stimuli were presented in white font on a black background.

The set of 64 filler words from Experiment 2 was used to space experimental prime-target pairs appropriately.

Procedure. Stimulus presentation and trial procedure were identical to those in Experiment 4; stimuli subtended a visual angle of approximately 2.6° (short) to 4.6° (long), with the inner edge constantly presented at a visual angle of 2° . Participants viewed 24 experimental stimuli each in separate Hindi and Urdu blocks. Within a block, equal numbers of experimental targets were paired with morphological, form and control primes. Each language block was presented in two sets of 40 trials each, separated by a pause for rest. Order of items within a set was fixed, ensuring a constant interval of nine items (i.e., lag 10) between respective primes and targets, but order of sets within blocks randomized. Multiple versions of the experiment were created such that each target was paired once with each of its three primes per combination of Script and Visual Field. Language order and versions were counterbalanced across participants, and no reader saw a stimulus (either prime or target) more than once.

Results

Due to equipment malfunction, data from one participant were incomplete and had to be rejected; data from two additional participants were removed due to extremely slow responses (the participant's average

response time was greater than the group's average by over two standard deviations). Results from the remaining 23 participants are reported here.

Visual Field Asymmetries for Hindi and Urdu Filler Words. Mean accuracy and response latencies for filler items were analyzed (see Table 8), and subjected separately to 2 (Script: Hindi, Urdu) \times 2 (Visual Field: right, left) within-subjects ANOVA. Reaction time outliers (response latencies below 250ms and above 1750ms) were removed, eliminating 0.9% of trials in Hindi and 1.8% in Urdu. Accuracy data yielded a main effect of Script [$F(1, 22) = 10.67, p < .05, MSE = 0.010, \eta^2 = .33$], indicating significantly greater accuracy in Hindi (92.1%) as compared to Urdu (85.5%). No effect of Visual Field emerged ($p > .10$), nor did the two variables interact. The RT analysis revealed no effect of Script ($p > .10$), but a significant main effect of Visual Field [$F(1, 22) = 11.11, p < .05, MSE = 951.59, \eta^2 = .34$], as well as a two-way interaction, $F(1, 22) = 16.05, p < .05, MSE = 1300.62, \eta^2 = .42$. Tests of simple effects revealed a significant advantage for the RVF in Hindi [$F(1, 44) = 27.16, p < .05, MSE = 1126.11, \eta^2 = .38$], but no difference between visual fields in Urdu ($F < 1$).

Visual Field Asymmetries for Hindi and Urdu Targets. Trimming of outlier trials (RT shorter than 250ms and longer than 1750ms) eliminated 0.9% and 1.9%, respectively, of Hindi and Urdu data.

Table 8

Exp. 5: Participants' naming latency (RT) and proportion accuracy in right vs. left visual field (RVF/LH vs. LVF/RH) presentations of Hindi vs. Urdu filler words (n = 23)

	Hindi		Urdu	
	Mean RT	Accuracy	Mean RT	Accuracy
RVF/LH	579 (19) ¹	0.92 (0.02)	582 (23)	0.86 (0.02)
LVF/RH	528 (19)	0.92 (0.02)	591 (24)	0.85 (0.03)

¹Standard Error values in parentheses.

Participants' mean accuracy revealed a marginal advantage for Hindi over Urdu, $F(1, 22) = 3.06$, $p < .09$, $MSE = 0.017$, $\eta^2 = .12$, but no effect of either Prime Type or Visual Field ($ps > .10$). There were no significant interactions. (Refer to Table 9 for condition-wise means.)

The RT analysis yielded main effects of all three factors—Script [$F(1, 22) = 4.41$, $p < .05$, $MSE = 28550.92$, $\eta^2 = .17$], Prime Type [$F(2, 44) = 3.72$, $p < .05$, $MSE = 9084.67$, $\eta^2 = .15$] and Visual Field [$F(1, 22) = 6.47$, $p < .05$, $MSE = 6480.65$, $\eta^2 = .23$]. In addition, Script was found to interact with Prime Type [$F(2, 44) = 3.20$, $p = .05$, $MSE = 7277.04$, $\eta^2 = .23$] as well as Visual Field [$F(1, 22) = 8.86$, $p < .05$, $MSE = 5463.65$, $\eta^2 = .29$]. Simple effects analysis of the Script by Prime Type interaction

revealed a significant influence of Prime Type in Urdu, with $F(2, 88) = 3.34$, $p = .05$, $MSE = 8180.85$, $\eta^2 = .05$, but not in Hindi ($p > .10$).

Further contrasts (family-wise $\alpha = .02$) revealed that the effect of Prime Type in Urdu arose from a marginal advantage of the morphological condition over the form condition [$F(1, 88) = 4.13$, $p < .05$, $MSE = 8180.85$, $\eta^2 = .04$] as well as the unrelated condition [$F(1, 88) = 3.12$, $p = .08$, $MSE = 8180.85$, $\eta^2 = .03$]. Conversely, tests of simple effects

Table 9

Exp. 5: Participants' word naming latency (RT) and proportion accuracy in right vs. left visual field (RVF/LH vs. LVF/RH) presentations of Hindi vs. Urdu targets cued by morphological (Morph), form-overlapping (Form) and unrelated (Control) primes ($n = 23$)

Visual Field	Prime	Hindi		Urdu	
	Type	Mean RT	Accuracy	Mean RT	Accuracy
RVF/LH	Morph	537 (20) ¹	1.00 (0.00)	604 (26)	0.94 (0.03)
	Form	544 (22)	0.93 (0.03)	643 (38)	0.95 (0.03)
	Control	591 (29)	0.97 (0.02)	646 (30)	0.94 (0.03)
LVF/RH	Morph	615 (23)	0.96 (0.02)	579 (21)	0.96 (0.02)
	Form	592 (24)	0.93 (0.03)	649 (30)	0.89 (0.03)
	Control	618 (26)	0.94 (0.03)	646 (31)	0.89 (0.04)

¹Standard error values in parentheses.

showed that the effect of Visual Field was confined to Hindi word naming latency, with a significant advantage for RVF trials over the LVF, $F(1, 44) = 5.03$, $p < .05$, $MSE = 5463.65$, $\eta^2 = .10$, but no difference was found in Urdu ($F < 1$).

Post-hoc contrasts (family-wise $\alpha = .004$) computed in an attempt to identify differences in priming asymmetry between Hindi and Urdu revealed no significant differences among the three priming conditions in either visual field in either Hindi or Urdu (all $ps > .004$). The Urdu data revealed a marginal advantage for the morphological over form conditions in LVF trials, $F(1, 176) = 7.22$, $p < .008$, $MSE = 7809.28$, $\eta^2 = .04$. See Figure 8 for a graph of the effects of the three variables, Script, Prime Type and Visual Field on Hindi and Urdu word naming latency.

Discussion

The present experiment assessed visual field asymmetry in morphological priming among two- and three-syllable words in Hindi vs. Urdu. Preliminary analyses of filler words replicated the accuracy advantage for Hindi over Urdu word naming. Filler naming latencies also confirmed and extended the RVF advantage in naming one-syllable Hindi words (Exp. 4) to words of two and three syllables. Additionally,

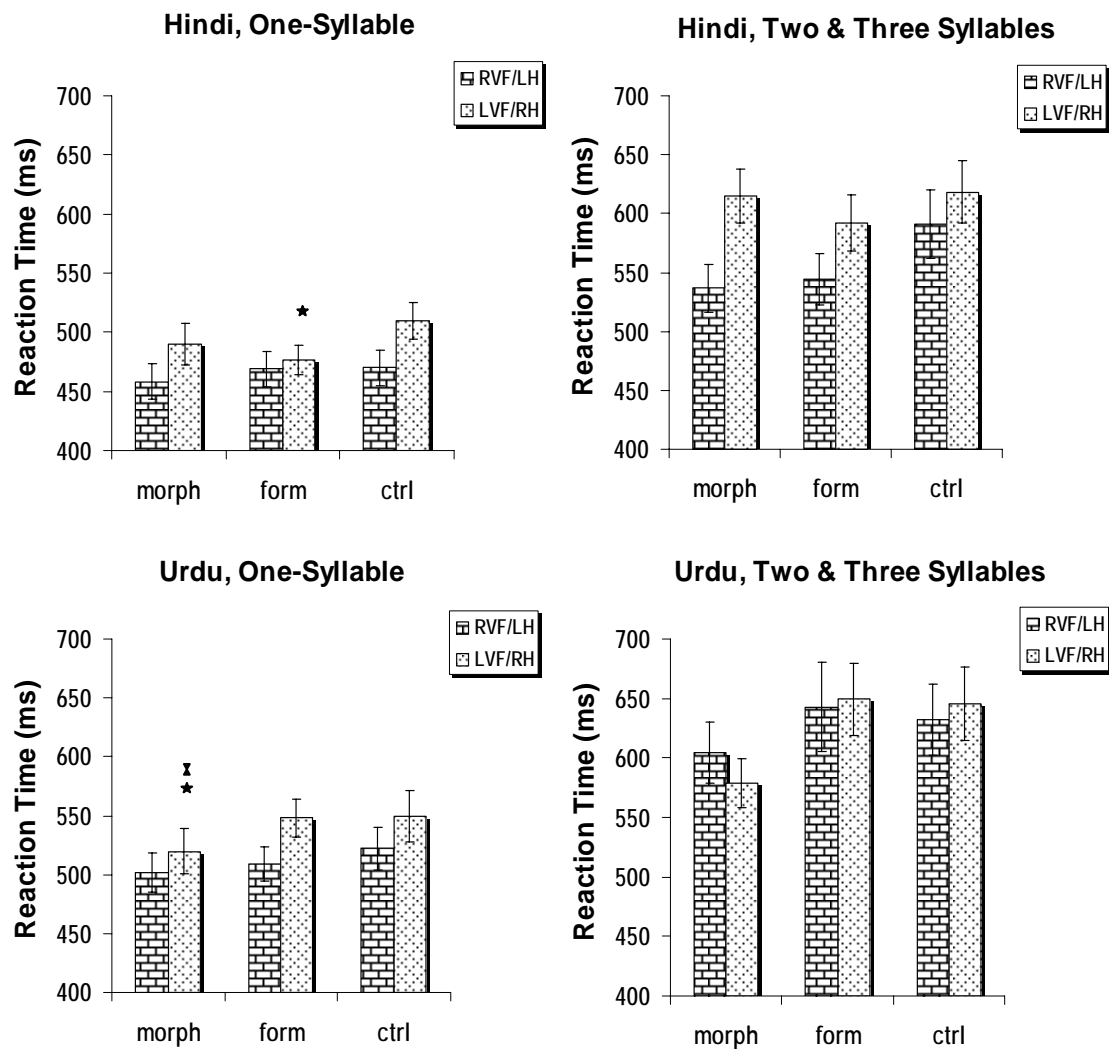


Figure 8 – Exps. 4 & 5: Participants' naming latencies to one, two and three syllable Hindi and Urdu words in morphological (morph), form-overlapping (form) and control (ctrl) conditions within right (RVF/LH) and left visual fields (LVF/RH). Significant priming relative to control indicated by * (.05); superiority of morphological over form condition indicated by ✕ (.05).

latencies to filler items revealed a lack of visual field asymmetry in Urdu; this pattern reinforced the conclusion in Experiment 4 that hemispheric asymmetry in word recognition is weaker in Urdu than in Hindi.

Data from the priming manipulation additionally confirmed that words in Hindi were named marginally more accurately ($MD = 2\%$) and significantly faster ($MD = 43\text{ms}$) than in Urdu. Naming latencies further revealed that responses to morphologically cued Urdu words were marginally faster than to targets in the form condition ($MD = 54\text{ms}$, $p = .008$). No difference among priming conditions emerged in Hindi. On the other hand, Hindi naming latencies revealed a reliable RVF advantage ($MD = 51\text{ms}$, $p < .03$), whereas response latencies in Urdu were equivalent across visual fields.

Contrasts computed to identify morphological priming effects showed that the numerical advantage recorded for morphological over unrelated Hindi targets in the RVF did not reach statistical significance ($MD = 54\text{ms}$, $p < .05$). In comparison with the RVF, latencies to Hindi words in the LVF were nearly equal across morphological and form conditions ($MD = 3\text{ms}$).

By contrast, Urdu naming latencies revealed numerical trends for a morphological advantage in both visual fields. In the RVF, the morphological condition showed a moderate numerical advantage over control ($MD = 39\text{ms}$) as well as form conditions ($MD = 42\text{ms}$); in LVF

presentations, Urdu morphological targets exhibited a large, marginally significant advantage with respect to control ($MD = 66\text{ms}$, $p < .02$) and form-overlapping targets ($MD = 70\text{ms}$, $p < .02$).

The lack of clear priming effects in either Hindi or Urdu in Experiment 5 may be due to the cost involved in processing longer, low frequency words. Previous work we have conducted has demonstrated that low frequency words of two syllables elicited significantly longer and less accurate lexical decisions in Hindi as well as Urdu (Vaid et al., 2008a). Although the stimuli used in the current experiment were adjudged to be of moderate frequency by Hindi/Urdu readers, it is thought that these estimates may have been inflated by the well-documented effect of morphological family size in boosting perceived familiarity of words (Baayen, Lieber & Schreuder, 1997; Schreuder & Baayen, 1997).

In conclusion, Experiment 5 further confirmed the existence of a reliable right visual field advantage in Hindi bi- and tri-syllabic word naming. By contrast, Urdu words exhibited no asymmetry between right and left visual fields, suggesting that the greater orthographic depth of Urdu script may attenuate hemispheric asymmetry in processing Urdu. No evidence of morphological priming was found in either Hindi or Urdu in this experiment, although the results revealed a marginally significant

numerical advantage for morphologically primed over unrelated targets in the RVF in Hindi, and in the LVF in Urdu.

GENERAL DISCUSSION

Experiments 4 and 5 were conducted in order to examine the hypothesis that the difference in orthographic depth between Hindi and Urdu modulates patterns of hemispheric asymmetry in morphological processing in the two languages. This view was contrasted with theories which attribute increased right hemisphere capacity for morphological processing to non-concatenative morphological structure (Eviatar & Ibrahim, 2007) and/or greater morphological productivity (Laine & Koivisto, 1998). Both these views would predict that Hindi and Urdu should exhibit similar patterns of hemispheric asymmetry inasmuch as they are morphologically the same; thus, if divergent patterns of asymmetry are nevertheless found for Hindi and Urdu the orthographic depth mediation view would be supported.

Analysis of filler words in Experiments 4 and 5 showed that the basic pattern of visual field asymmetry in Hindi mirrors that of English and other languages, yielding a consistent advantage for the RVF over the LVF (Hellige, 2001). Urdu also exhibited a RVF advantage but this was restricted to one-syllable words, complementing previous findings of LH dominance in Urdu lexical processing (Adamson & Hellige, 2006; Vaid, 1988). However, responses to two- and three-syllable Urdu words were more variable, exhibiting either no effect of visual field or an LVF

bias. This finding suggests that hemispheric dominance may be reduced in Urdu as compared to Hindi word recognition.

An unexpected finding was the absence of reliable morphological priming in Hindi in both experiments, although a numerical trend in both Experiments 4 and 5 indicated an advantage for morphologically primed relative to unrelated targets only in the RVF. The lack of priming in the RVF in Hindi was attributed to ceiling-level performance in identifying lateralized, one-syllable Hindi words (Exp. 4), and to an overshadowing cost of processing low frequency, two-syllable words in Experiment 5. An alternative explanation of the above findings, however, is that the use of a prime-target interval of several seconds (10 trials) in these experiments may have led to the complete dissipation of morphological priming in Hindi. Further investigation using varying intervals between prime and target is needed in order to establish the validity of this argument.

Data from Urdu in the above experiments provided stronger evidence of morphological priming than in Hindi. In Experiment 4, Urdu exhibited a clear LVF bias in morphological priming, whereas in Experiment 5, both visual fields showed a numerical advantage for morphological relative to unrelated primes, although the difference did not reach significance in the RVF and was marginally significant in the LVF. These results suggested that the hemispheric bias in morphological

processing might be attenuated for the orthographically deep Urdu script, although the absence of a clear contrast between Hindi and Urdu dilutes this interpretation.

Nevertheless, the findings from Experiments 4 and 5 do make a case for the moderating influence of orthographic depth on hemispheric asymmetry in visual word recognition. In both experiments, the shallow Hindi script evinced a strong right visual field/left hemisphere bias, whereas in Urdu, the left hemisphere bias was limited to words of one-syllable; no clear advantage was observable for either visual field in processing Urdu words of two and three syllables. The Urdu results thus offer partial support for the earlier findings of Melamed and Zaidel (1993), who demonstrated an absence of visual field asymmetry in Farsi word recognition. Importantly, the combined results in Hindi and Urdu strengthen the argument that the degree of left hemisphere dominance in written language processing is a function of the orthographic depth of the writing system (Hatta et al., 1983; Leong et al., 1985; Sasanuma et al., 1977, 1980; Yamaguchi et al., 2002; Yang, 1999).

The use of a novel experimental paradigm in the current experiments may be in some way responsible for the weak effect of morphological primes recorded in Experiments 4 and 5. The decision to combine the visual hemifield technique with a primed naming task in Experiments 4 and 5 represented a solution to the challenge presented

by Urdu, whose unvoweled script makes it difficult for readers to distinguish real words from pseudowords, leading to the rejection of pseudowords as testing materials. This in turn precluded the use of the lateralized lexical decision task which researchers have traditionally used to index asymmetry in morphological processing, e.g., Eviatar & Ibrahim, 2007; Koenig et al., 1992).

The necessity of limiting stimuli to actual words led to the use of priming as an index of morphological effects. An additional innovation was the use of the long-term priming paradigm, preferred over immediate priming due to the absence of a case distinction in Hindi/Urdu. The lack of upper vs. lower case in Hindi and Urdu script means that briefly presented contiguous primes and targets cannot be distinguished in these languages.

Notwithstanding the solutions we implemented for script-specific problems, the procedure used in Experiments 4 and 5 has no precedent, and interpretation of results must be tempered by this consideration. Evidence from well-established experimental paradigms is therefore needed in order to establish the reliability of the pattern of visual field asymmetry in morphological processing we observed for Hindi vs. Urdu.

A possible solution in future research to the problems outlined above might be to compare lateralized naming of morphologically decomposable versus non-decomposable words closely matched in

phonological and orthographic structure. To illustrate, morphologically decomposable words such as *brother* should incur a processing cost relative to *brothel* in the hemisphere that is responsible for morphological processing; the Hindi/Urdu words /□halnā/ vs. /□halnī/ (*to cheat* vs. *sieve*) may be similarly compared. If the LH is exclusively responsible for morphological processing, the cost of processing decomposable words should be limited to the RVF, whereas a reduced asymmetry between hemispheres should result in a disadvantage for decomposable over non-decomposable words in both visual fields.

The variability of visual field asymmetry in Urdu word recognition also requires further investigation. In Experiments 4 and 5, short, one-syllable Urdu words were processed more efficiently in the RVF, whereas longer words did not reveal a clear advantage for either visual field. One explanation is that this distinction in processing short vs. long Urdu words arises from the difference in the visual angle subtended by these stimuli, that is, that RVF superiority in word processing is nullified by the additional cost of visual scanning for long words whose beginning lies far outside central vision in a direction opposing typical scanning motions in the right-to-left Urdu script. Alternatively, long words in Urdu may actually be processed more readily in the LVF as compared to the RVF. A third possibility is that the LH, although being more

competent than the RH at processing long words, may still require greater time and effort to process such stimuli, thus nullifying any visual field asymmetry. More evidence is thus needed in order to evaluate the alternative explanations.

CONCLUSIONS AND FUTURE DIRECTIONS

In the present research, five experiments were conducted to examine the influence of orthographic depth on the processing of word morphology. The language pair of Hindi and Urdu was chosen as an ideal contrast for this research, owing to the nearly identical morphophonology and common grammar of these languages, combined with distinct orthographic expression.

Experiments 1, 2 and 3 examined the combined effect of prime exposure duration and presentation condition (masked vs. unmasked primes) on morphological priming in Hindi and Urdu. These results revealed that only the orthographically shallow Hindi script exhibited early-arising morphological priming by masked primes. In contrast, the deep Urdu orthography exhibited morphological priming at longer prime exposure, under masked prime presentation. The qualitative nature of the difference in morphological priming between Hindi and Urdu was underscored by the effect of masking: at the 48ms SOA, the presence of the mask was critical to inducing superior morphological priming in Hindi, whereas it suppressed morphological effects in Urdu. At the 240ms SOA, the inclusion of the mask suppressed morphological effects in Hindi, but stimulated morphological superiority in Urdu.

Experiments 4 and 5 assessed whether orthographic depth mediates the pattern of hemispheric asymmetry in morphological priming. Naming of unilaterally presented, one-syllable, Hindi words in experiment 4 revealed a small, non-significant advantage for morphological over form primes (11ms) only in RVF presentations, while a similar, marginally significant trend (54ms) was observed for words of two and three syllables in experiment 5. The Urdu data exhibited a reliable morphological priming effect for one-syllable words presented to the LVF in experiment 4, and a numerical advantage for morphologically primed words of two and three syllables in experiment 5. In combination, these results suggested that hemispheric bias in morphological processing may be influenced by orthographic depth, although the lack of statistically significant effects points to the need for more conclusive evidence.

Data from filler stimuli in experiments 4 and 5 additionally confirmed an RVF bias in Hindi word recognition, combined with a mixed pattern of asymmetry in Urdu. An RVF advantage for one-syllable Urdu words was contrasted with a lack of visual field asymmetry in naming longer words. Overall, these data were interpreted as supporting the hypothesis that orthographic depth influences hemispheric asymmetry in word recognition.

Implications for Models of Morphology

To sum up, the research presented here offers clear support for the thesis that morphological processing strategy is influenced by orthographic depth, that is, phonological transparency of written language. While the precise nature of this influence remains to be delineated, the current findings have implications for models of morphological processing. The above results suggest that the exclusive emphasis on morphological structure and productivity in current models requires re-evaluation.

The first step in this process must be to confirm the role of orthographic depth in mediating morphological processing in other languages, for example, by comparing morphological priming among cognates in two languages with varying orthographic depth, such as English and Spanish. A second, equally important requirement is to gain a deeper understanding of morphological processing in languages that, at present, offer the strongest evidence in favor of morphological organization of the mental lexicon, namely non-concatenative languages.

In this direction, the role of orthographic depth may be better gauged by comparing morphological priming in non-concatenative languages with varying orthographic depth. Valuable insights can thus be gained by contrasting morphological priming in the phonologically opaque Arabic and Hebrew with that in the relatively transparent

orthographies of Coptic and Maltese (Kramer, 2007; Twist & Ussishkin, 2007).

Significance to Research on Hemispheric Asymmetry

The results of Experiments 4 and 5 have additional implications for research on the functional asymmetries in word recognition. Although behavioral evidence suggests that hemispheric bias in processing words may be reduced for orthographically deep languages, the present study represents the first attempt to relate orthographic depth to morphological processing asymmetry. Despite the lack of conclusive evidence, the trend revealed by Experiments 4 and 5 suggested that the exclusive right visual field/left hemisphere advantage in processing Hindi is not mirrored in the phonologically opaque Urdu script. These findings highlight the need for systematic investigation of hemispheric contributions to morphological processing.

In this context, it must be noted that the only study thus far to record neuropsychological support for right hemisphere morphological processing found a correlation between RH damage and processing of Italian devotional morphology (Marangolo, Incoccia, Pizzamiglio, Sabatini, Castriota-Scanderbeg & Burani, 2003). The contrast in orthographic depth juxtaposed with the richness of inflected morphology

in these languages further highlights the need for systematic investigation of hemispheric contributions to morphological processing.

Psycholinguistic Value of Hindi and Urdu

Apart from its implications for research on morphology in general, the current study turned the spotlight on morphological processing in the relatively little investigated languages Hindi and Urdu. The shared phonology and morphology of Hindi/Urdu, combined with the distinct orthographies used to represent these languages offers a fertile ground for investigating the degree to which form subserves morphological representation and processing. As such, this study presents preliminary findings suggesting that the orthographic differences between Hindi and Urdu are responsible for mediating different patterns of morphological priming in Hindi vs. Urdu (Exps. 1 – 3) and for variations in hemispheric asymmetry of morphological priming (Exps. 4 and 5).

Confirmation of Morpho-orthographic Decomposition. Nevertheless, additional corroboration is required in order to establish an orthographic basis for the Hindi-Urdu differences in morphological priming. Unambiguous proof of such dissociation might be furnished by demonstrating that priming based on morpho-orthographic similarity is limited to the phonologically transparent Hindi orthography. It was stated earlier that the shallow orthography of Hindi precludes the

existence of morphologically opaque word-pairs such as *brother* – *broth*. However, it is speculated that morpho-orthographic priming may be observable among Hindi/Urdu words whose morphological relatives have multiple readings.

For example, one reading of /ghu□nā/ (*to stifle*) has the stem form /ghu□/ (*stifle*), as well as inflections such as /ghu□ne/ (*to stifle*), /ghu□tā/ (*being stifled*) and /ghu□kar/ (*having stifled*); the second reading of /ghu□nā/ (*knee*) is related to the inflections /ghu□ne/ and /ghu□nō/ (both translatable as *knees*). It is speculated that the existence of identical inflections of the two words (/ghu□nā/, /ghu□ne/) should encourage morpho-orthographic priming between the incongruent pair /ghu□nō/ – /ghu□/ (*knees* - *stifle*), but that more extensive prime processing should inhibit such priming.

The current results may then be extended to predict that under heavily masked, briefly exposed prime presentation, recognition of Hindi targets such as /ghu□/ should be equivalently facilitated by congruent (e.g., /ghu□kar/) as well as incongruent inflections (/ghu□nō/), whereas unmasked primes exposed for long durations should encourage priming only by congruent inflections (/ghu□kar/ – /ghu□/). Moreover, this dichotomy should be apparent only in Hindi, whereas priming in Urdu should be exclusive to congruent pairs.

Role of Morphophonological Overlap. The contrast between Hindi and Urdu can also furnish insights into the contribution of phonology to morphological processing. Investigators have recently acknowledged that morphological priming effects which were hitherto ascribed to morpho-orthographic decomposition may also reflect the degree of phonological overlap between primes and targets (Gonnerman, Seidenberg & Andersen, 2007; Tsapkini et al., 1999; Widmann & Morris, 2009). Widmann and Morris (2009) demonstrated that the magnitude of priming among morphologically opaque words was larger for phonologically similar (*cower* – *cow*) than for dissimilar pairs (*cater* – *cat*).

It was previously suggested that the role of form overlap in mediating morphological priming in Hindi/Urdu might be further assessed by comparing facilitation by morphological primes whose first syllable was identical to the target (/mo□nā/ – /mo□/, *cause to turn* – *turn*) against that by primes with a different initial syllable (/mu□nā/ – /mo□/, *to turn* – *turn*). As a further step, the uniquely phonological contribution to morphological priming may be determined by minimizing orthographic priming in this experiment; it is suggested here that removal of the *header bar* (/□irorehkā/) from primes may provide a means of reducing the degree of orthographic overlap in prime-target pairs. The header bar is a typical feature of Hindi script, and previous research in our laboratory shows that the removal of this feature

reduces recognition speed and accuracy in Hindi, but does not prevent identification of words (Vaid, Rao & Chen, 2006).

Morphosyntactic Processing in Hindi and Urdu. Arguably the most valuable contribution of Hindi/Urdu to psycholinguistic research on morphology might derive from their potential ability to illuminate the mechanisms underlying discourse level morphological processing. That is, morphological expression in Hindi/Urdu relies not only on the inflection and derivation of individual words, but on the agreement of morphological markers across phrases and sentences (Kachru, 2006; Masica, 1991). The examples in Figure 3 illustrated the importance of congruence among morphological markers for expressing concepts such as gender, tense and number in Hindi/Urdu. Despite the interest in discourse processing in Hindi (Baum, Dwivedi & Shah, 2004; Shah, Baum & Dwivedi, 2006; Vasishth, 2003; Vasishth & Lewis, 2006; Vasishth, Sukow, Lewis & Kern, in press), only two published studies thus far have examined morphological phenomena in Hindi at the syntactic level (Dillon, Nevins, Austin & Phillips, submitted; Nevins, Dillon, Malhotra & Phillips, 2007).

Using Event Related Potentials (ERP) to measure readers' responses to grammatical incongruity, Nevins and colleagues investigated the effects of different types of errors in Hindi on negative and positive deflections in ERP. Most importantly, Dillon et al. (2009)

demonstrated a distinction between lexical and syntactic levels of morphological processing in Hindi. In their study, errors in grammatical tense that were cued by semantic vs. morphosyntactic markers elicited significantly different ERP patterns. Thus, semantically marked tense errors (analogous to, *'last Saturday, I sprint to school'*) led to diffuse, early-arising, posterior ERP negativity (200–400ms), whereas morphosyntactically marked errors (e.g., *'I panted as I sprint to school'*) gave rise to right-biased, anterior, later arising negativity (300–500ms) as well as a larger P600 component. Additionally, Nevins et al. (2007) demonstrated significant but equivalent increases in the P600 component in response to morphosyntactic errors relating to person, gender and number marking.

The influence of script-specific (orthographic) differences in regulating morphological processing of Hindi/Urdu at the supra-lexical level, however, remains unexplored. Future research might address this issue by contrasting morphosyntactic processing in Urdu with that in Hindi. It is worth noting here that Dillon et al. (2009) recorded a right hemispheric bias in processing morphosyntactic violations in Hindi. Nevertheless, the poor spatial resolution afforded by the ERP technique implies the need for corroborative evidence from more spatially precise neuropsychological indices such as those provided by fMRI and PET.

Ancillary Findings

Supplementing the major contributions of the present research were several corollary observations that were nonetheless theoretically and empirically interesting. These included the demonstration of a systematic influence of forward masking on morphological priming. An explanation for the distinct influence of masking on morphological priming in Hindi vs. Urdu was offered in a previous discussion and is therefore not repeated here; in brief, the effect of the forward mask at short as well as long prime exposures was attributed to the restrictive effect of the mask on prime processing, while its differential effect on Hindi vs. Urdu was attributed to the difference in the stages of lexical processing in the two languages.

Other phenomena of interest in the present results include the significant delay in naming Hindi and Urdu words at the 240ms SOA in experiments 1 to 3, as compared to naming latencies at the 48ms (Exps. 1, 2 and 3) and 80ms SOAs (Exp. 1); this effect was attributed to prime – target competition at advanced stages of prime processing. Additionally, Experiment 3 showed that targets that were two and three syllables in length failed to exhibit reliable priming in either Hindi or Urdu—greater syllable length as well as reduced form overlap were presented as alternative explanations for the weak effects observed in this experiment, and a test of the alternative explanations was suggested.

Lack of significant morphological priming in Hindi in the lateralized naming experiments (4 and 5) also presents an avenue for future research. This pattern was speculatively attributed to ceiling effects in naming one-syllable words (Exp. 4) and to an overshadowing cost of syllable length in naming words of two and three syllables (Exp. 5); however, the results invite further research on long-term morphological priming in Hindi. The effect of syllable length on lateralization of word recognition in Urdu similarly calls for methodical inquiry.

Broader Impact

Beyond cognitive-linguistic ramifications, the present study marks an addition to the literature on language processing in Hindi and Urdu. In addition to providing a unique psycholinguistic contrast, these languages motivate research interest for a number of reasons, including a large population of speakers (approximately 480 million users of Hindi/Urdu across 21 countries, cf. Ethnologue.com), sociopolitical significance (Hindi is the national language of India, while Urdu is the national language of Pakistan), as well as the limited volume of extant research.

There is at present only a small body of research on visual word recognition in Hindi and/or Urdu (Adamson & Hellige, 2006; Brown,

Sharma & Kirsner, 1984; Gupta, 2004; Gupta & Jamal, 2007; Mumtaz & Humphreys, 2002; Rao et al., submitted; Vaid, 1988; Vaid & Gupta, 2002), and some work on discourse processing in Hindi (Baum et al., 2004; Dillon et al., submitted; Kumar, Das, Bapi, Padakannaya, Joshi & Singh, 2009; Nevins et al., 2007; Shah et al., 2006; Vasishth, 2003; Vasishth & Lewis, 2006; Vasishth et al., in press) but no research published hitherto addressed primed word recognition in Hindi or Urdu. As such, this study marks a groundbreaking endeavor in this area.

By way of conclusion, the impact of this study may be summarized as follows. Firstly, we demonstrated that orthographic depth contributes distinctly to morphological processing strategy, beyond the known influences of morphological characteristics such as structure (typology) and productivity (richness and consistency). Secondly, this research supported the view that cerebral hemispheric involvement in word recognition is mediated by orthographic depth. Lastly, the research made a significant contribution to existing knowledge on visual word recognition in two relatively under-studied but cognitively unique and sociolinguistically interesting languages, Hindi and Urdu.

REFERENCES

- Adamson, M. M., & Hellige, J. B. (2006). Hemispheric differences for identification of words and nonwords in Urdu-English bilinguals. *Neuropsychology*, **20**, 232-248.
- Ahmad, R. (2008). Scripting a new identity: The battle for Devanagari in nineteenth century India. *Journal of Pragmatics*, **40**, 1163-1183.
- Allen, M. & Badecker, W. (1999). Stem homograph inhibition and stem allomorphy: Representing and processing inflected forms in a multilevel lexical system. *Journal of Memory & Language*, **41**, 105-123.
- Andrews, S. (1986). Morphological influences on lexical access: Lexical or nonlexical effects? *Journal of Memory & Language*, **25**, 726-740.
- Aronoff, M. (1976). *Word formation in generative grammar*. Cambridge, MA: MIT Press.
- Aronoff, M., & Fudeman, K.A. (2004). Thinking about morphology and morphological analysis. In M. Aronoff, & K. A. Fudeman (Eds.), *What is morphology?* (pp. 1-31). Oxford, UK: Blackwell.
- Baayen, R. H., Lieber, R., & Schreuder, R. (1997). The morphological complexity of simplex nouns. *Linguistics*, **35**, 861-877.
- Badecker, W., & Caramazza, A. (1991) Morphological composition in the lexical output system. *Cognitive Neuropsychology*, **8**, 335-32.

- Baum, S., Dwivedi, V, & Shah, A. (2004). Prosodic production and domain sensitivity in brain-damaged patients. *Brain & Language*, **91**, 56-57.
- Baynes, K., Tramo, M. J., & Gazzaniga, M. S. (1992). Reading in the right hemisphere of a callosotomy patient. *Neuropsychologia*, **30**, 187-200.
- Beeman, M. J., & Chiarello, C. (1998). Complementary right- and left-hemisphere language comprehension. *Current Directions in Psychological Science*, **7**, 2-8.
- Bentin, S. (1989). Orthography and phonology in lexical decision: Evidence from repetition effects at different lags. *Journal of Experimental Psychology: Learning, Memory & Cognition*, **15**, 61-72.
- Bentin, S., Bargai, N., & Katz, L. (1984). Orthographic and phonemic coding for lexical access: Evidence from Hebrew. *Journal of Experimental Psychology: Learning Memory & Cognition*, **10**, 353-368.
- Bentin, S., & Feldman, L. B. (1990). The contribution of morphological and semantic relatedness to repetition priming at short and long lags: Evidence from Hebrew. *Quarterly Journal of Experimental Psychology Section-A: Human Experimental Psychology*, **42**, 693-711.

- Bentin, S., & Frost, R. (1987). Processing lexical ambiguity and visual word recognition in a deep orthography. *Memory & Cognition*, **15**, 13-23.
- Bentin, S., & Ibrahim, R. (1996). New evidence for phonological processing during visual word recognition: The case of Arabic. *Journal of Experimental Psychology: Learning Memory & Cognition*, **22**, 309-323.
- Beretta, A., Campbell, C., Carr, T., Huang, J., Schmitt, L., Christianson, K., & Cao, Y. (2003). An ER-fMRI investigation of morphological inflection in German reveals that the brain makes a distinction between regular and irregular forms. *Brain & Language*, **85**, 67-92.
- Bertram, R., Baayen, R. H., & Schreuder, R. (2000). Effects of family size for complex words. *Journal of Memory & Language*, **42**, 390-405.
- Bick, A., Goelman, G., & Frost, R. (2008). Neural correlates of morphological processes in Hebrew. *Journal of Cognitive Neuroscience*, **20**, 406-420.
- Bodner, G. E., & Masson, M. E. J. (1997). Masked repetition priming of words and nonwords: Evidence for a nonlexical basis for priming. *Journal of Memory & Language*, **37**, 268-293.
- Bornkessel, I., Zysset, S., Friederici, A. D., von Cramon, D. Y., & Schlesewsky, M. (2005). Who did what to whom? The neural basis

of argument hierarchies during language comprehension.

Neuroimage, **15**, 221-233.

Boudelaa, S., & Marslen-Wilson, W. D. (2001). Morphological units in the Arabic mental lexicon. *Cognition*, **81**, 65-92.

Boudelaa, S., & Marslen-Wilson, W. D. (2004). Allomorphic variation in Arabic: Implications for lexical processing and representation. *Brain & Language*, **90**, 106-116.

Boudelaa, S., & Marslen-Wilson, W. D. (2005). Discontinuous morphology in time: Incremental masked priming in Arabic. *Language & Cognitive Processes*, **20**, 207-260.

Bozic, M., Marslen-Wilson, W. D., Stamatakis, E. A., Davis, M. H., & Tyler, L. K. (2007). Differentiating morphology, form and meaning: Neural correlates of morphological complexity. *Journal of Cognitive Neuroscience*, **19**, 1464-1475.

Brown, H., Sharma, N. K., & Kirsner, K. (1984). The role of script and phonology in lexical representation. *Quarterly Journal of Experimental Psychology Section-A: Human Experimental Psychology*, **36**, 491-505.

Bub, D. N., & Lewine, J. (1988). Different modes of word recognition in the left and right visual fields. *Brain & Cognition*, **33**, 161-188.

Burani, C., & Caramazza, A. (1987). Representation and processing of derived words. *Language & Cognitive Processes*, **2**, 217-227.

- Burgess, C., & Skodis, J. (1993). Lexical representation and morphosyntactic parallelism in the left hemisphere. *Brain & Language*, **44**, 129-138.
- Bybee, J. (1985). *Morphology: A study of the relation between meaning and form*. Amsterdam, The Netherlands: John Benjamins.
- Cappelletti, M., Fregni, F., Shapiro, K., Pascual-Leone, A., & Caramazza, A. (2008). Processing nouns and verbs in the left frontal cortex: A Transcranial Magnetic Stimulation study. *Journal of Cognitive Neuroscience*, **20**, 707-720.
- Caramazza, A., & Hillis, A.E. (1991). Lexical organization of nouns and verbs in the brain. *Nature*, **349**, 788-790.
- Caramazza, A., Laudanna, A. & Romani, C. (1988). Lexical access and inflectional morphology. *Cognition*, **28**, 297-332.
- Cardona, G., & Jain, D. (2003). *The Indo-Aryan languages*. London: Routledge.
- Chiarello, C. (1985). Hemisphere dynamics in lexical access: Automatic and controlled priming. *Brain & Language*, **26**, 146-172.
- Chiarello, C. (1991). Interpretation of word meanings by the cerebral hemispheres: One is not enough. In P. Schwanenflugel (Ed.), *The psychology of word meanings* (pp. 251-278). Hillsdale, NJ: Erlbaum.

- Christman, S., & Pinger, K. (1997). Lateral biases in aesthetic preferences: Pictorial dimensions and neural mechanisms. *Laterality*, **2**, 155-175.
- Crossman, D. L., & Polich, J. (1988). Hemispheric differences for orthographic and phonological processing. *Brain & Language*, **35**, 301-312.
- Dennis, W., & Raskin, E. (1960). Further evidence concerning the effect of handwriting habits upon the location of drawings. *Journal of Consulting Psychology*, **24**, 548-549.
- Deutsch, A., Frost, R., & Forster, K. I. (1998). Verbs and nouns are organized and accessed differently in the mental lexicon: Evidence from Hebrew. *Journal of Experimental Psychology: Learning Memory & Cognition*, **24**, 1238-1255.
- Devlin, J. T., Jamison, H. L., Matthews, P. M., & Gonnerman, L. M. (2004). Morphology and the internal structure of words. *Proceedings of the National Academy of Sciences, U.S.A.*, **101**, 14984-14988.
- Diependaele, K., Sandra, D., & Grainger, J. (2005). Masked cross-modal morphological priming: Unravelling morpho-orthographic and morpho-semantic influences in early word recognition. *Language & Cognitive Processes*, **20**, 75-114.

- Dillon, B., Nevins, A., Austin, A. C., & Phillips, C. (2009). *Syntactic and semantic predictors of tense in Hindi: An ERP investigation*. Manuscript submitted for publication.
- Dominguez, A., Cuetos, F., & Seguí, J. (1999). The processing of grammatical gender and number in Spanish. *Journal of Psycholinguistic Research*, **28**, 485-498.
- Drews, E. & Zwitserlood, P. (1995). Morphological and orthographic similarity in visual word recognition. *Journal of Experimental Psychology: Human Perception & Performance*, **21**, 1098-1116.
- Duñabeitia, J. A., Laka, I., Perea, M., & Carreiras, M. (2009). Is Milkman a superhero like Batman? Constituent morphological priming in compound words. *European Journal of Cognitive Psychology*, **21**, 615-640.
- Ellis, A. W. (2004). Length, formats, neighbours, hemispheres, and the processing of words presented laterally or at fixation. *Brain & Language*, **88**, 355-366.
- Ellis, A. W., Young, A. W., & Anderson, C. (1988). Modes of word recognition in the left and right cerebral hemispheres. *Brain & Language*, **35**, 254-273.
- Eviatar, Z. (1997). Language experience and right hemisphere tasks: The effects of scanning habits and multilingualism. *Brain & Language*, **58**, 157-173.

- Eviatar, Z. (1999). Cross-language tests of hemispheric strategies in reading nonwords. *Neuropsychology*, **13**, 498-515.
- Eviatar, Z., & Ibrahim, R., (2007). Morphological structure and hemispheric functioning: The contribution of the right hemisphere to reading in different languages. *Neuropsychology*, **21**, 470-484.
- Eviatar, Z., Ibrahim, R., & Ganayim, D. (2004). Orthography and the hemispheres: Visual and linguistic aspects of letter processing. *Neuropsychology*, **18**, 174-184.
- Faust, M., & Chiarello, C. (1998). Sentence context and lexical ambiguity resolution by the two hemispheres. *Neuropsychologia*, **36**, 827-835.
- Feldman, L. B. (1991). The contribution of morphology to word recognition. *Psychological Research*, **53**, 33-41.
- Feldman, L. B. (2000). Are morphological effects distinguishable from the effects of shared meaning and shared form? *Journal of Experimental Psychology: Learning Memory & Cognition*, **26**, 1431-1444.
- Feldman, L. B., & Andjelković, D. (1992). Morphological analysis in word recognition. In R. Frost & L. Katz (Eds.), *Orthography, phonology, morphology, and meaning: Advances in psychology* (pp. 343-360). Oxford, UK: North-Holland.

- Feldman, L. B., & Fowler, C. A. (1987). The inflected noun system in Serbo-Croatian: Lexical representation of morphological structure. *Memory & Cognition*, **15**, 1-12.
- Feldman, L. B. & Moskovljević, J. (1987). Repetition priming is not purely episodic in origin. *Journal of Experimental Psychology: Learning Memory & Cognition*, **13**, 573-581.
- Feldman, L. B., & Soltano, E. G. (1999). Morphological priming: The role of prime duration, semantic transparency, and affix position. *Brain & Language*, **68**, 33-39.
- Feldman, L. B., & Turvey, M. T. (1983). Word recognition in Serbo-Croatian is phonologically analytic. *Journal of Experimental Psychology: Human Perception & Performance*, **9**, 288-298.
- Fernandino, L., Iacoboni, M., & Zaidel, E. (2007). The effects of bilateral presentations on lateralized lexical decision. *Brain & Cognition*, **64**, 60-67.
- Forster, K. I. (1998). The pros and cons of masked priming. *Journal of Psycholinguistic Research*, **27**, 203-233.
- Forster, K. I., & Davis, C. (1984). Repetition priming and frequency attenuation in lexical access. *Journal of Experimental Psychology: Learning, Memory & Cognition*, **10**, 680-698.
- Forster, K. I., Davis, C., Schoknecht, C., & Carter, R. (1987). Masked priming with graphemically related forms: Repetition or partial

activation? *Quarterly Journal of Experimental Psychology*, **39**, 211-251.

Forster, K. I., Mohan, K., & Hector, J. (2003). The mechanics of masked priming. In S. Kinoshita & S. J. Lupker (Eds.), *Masked priming: The state of the art* (pp. 3-37). Hove, UK: Psychology Press.

Forster, K. I., & Veres, C. (1998). The prime lexicality effect: Form-priming as a function of prime awareness, lexical status, and discrimination difficulty. *Journal of Experimental Psychology: Learning, Memory, & Cognition*, **24**, 498-514.

Fowler, C. A., Napps, S. E., & Feldman, L. B. (1985). Relations among regular and irregular morphologically related words in the lexicon as revealed by repetition priming. *Memory & Cognition*, **13**, 241-255.

Frost, R., Deutsch, A., & Forster, K. I. (2000). Decomposing morphologically complex words in a nonlinear morphology. *Journal of Experimental Psychology: Learning Memory & Cognition*, **26**, 751-765.

Frost, R., Deutsch, A., Gilboa, O., Tannenbaum, M., & Marslen-Wilson, W. D. (2000). Morphological priming: Dissociation of phonological, semantic, and morphological factors. *Memory & Cognition*, **28**, 1277-1288.

- Frost, R., Forster, K. I., & Deutsch, A. (1997). What can we learn from the morphology of Hebrew? A masked priming investigation of morphological representation. *Journal of Experimental Psychology: Learning Memory & Cognition*, **23**, 829-856.
- Frost, R., Katz, L., & Bentin, S. (1987). Strategies for visual word recognition and orthographical depth: A multilingual comparison. *Journal of Experimental Psychology: Human Perception & Performance*, **13**, 104-115.
- Frost, R., Kugler, T., Deutsch, A., & Forster, K. I. (2005). Orthographic structure versus morphological structure: Principles of lexical organization in a given language. *Journal of Experimental Psychology: Learning Memory & Cognition*, **31**, 1293-1326.
- Gibson, A. R., Dimond, S. J., & Gazzaniga, M. S. (1972). Left field superiority for word matching. *Neuropsychologia*, **10**, 463-466.
- Giraudo, H., & Grainger, J. (2000). Effects of prime word frequency and cumulative root frequency in masked morphological priming. *Language & Cognitive Processes*, **15**, 421-444.
- Giraudo, H., & Grainger, J. (2001). Priming complex words: Evidence for supralelexical representation of morphology. *Psychonomic Bulletin & Review*, **8**, 127-131.

- Gold, B. T., & Rastle, K. (2007). Neural correlates of morphological decomposition during visual word recognition. *Journal of Cognitive Neuroscience*, **19**, 1983-1993.
- Gonnerman, L. M. (1999). Morphology and the lexicon: Exploring the semantics-phonology interface. *Dissertation Abstracts International – A*, 60 (06), 2004. (UMI No. 9933782).
- Gonnerman, L., Seidenberg, M. S., & Andersen, E. (2007). Graded semantic and phonological similarity effects in priming: Evidence for a distributed connectionist approach to morphology. *Journal of Experimental Psychology: General*, **136**, 323-345.
- Grainger, J., Colé, P., & Seguí, J. (1991). Masked morphological priming in visual word recognition. *Journal of Memory & Language*, **30**, 370-384.
- Greenberg, J. H. (1966). *Universals of language* (2nd ed.). Oxford, UK: MIT Press.
- Gupta, A. (2004). Reading difficulties in Hindi-speaking children with developmental dyslexia. *Reading & Writing*, **17**, 79-99.
- Gupta, A., & Jamal, G. (2007). Reading strategies of bilingual normally progressing and dyslexic readers in Hindi and English. *Applied Psycholinguistics*, **28**, 47-68.

Hagiwara, H., Ito, T., Sugioka, Y., Kawamura, M., & Shiota, J. (1999).

Neurolinguistic evidence for rule-based nominal suffixation.

Language, **75**, 739-763.

Hagoort, P., Indefrey, P., Brown, C., Herzog, H., Steinmetz, H., & Seitz,

R.J. (1999). The neural circuitry involved in the reading of German words and pseudowords: A PET study. *Journal of Cognitive*

Neuroscience, **11**, 383-398.

Hamilton, A.C., & Coslett, H. B. (2008). Role of inflectional regularity

and semantic transparency in reading morphologically complex

words: evidence from acquired dyslexia. *Neurocase*, **14**, 347-68.

Hatta, T., Katoh, H., & Aitani, N. (1983). Does single Kanji process

dominantly in the right hemisphere? Some implication from

Stroop test results. *International Journal of Neuroscience*, **18**, 67-71.

Heath, R. L., Mahmassani, O., Rouhana, A., & Nassif, N. (2005).

Comparison of aesthetic preferences among Roman and Arabic

script readers. *Laterality*, **10**, 399-411.

Hellige, J. B. (2001). *Hemispheric asymmetry: What's right and what's*

left. Cambridge, MA: Harvard University Press.

Hellige, J. B., & Yamauchi, M. (1999). Quantitative and qualitative

hemispheric asymmetry for processing Japanese Kana. *Brain &*

Cognition, **40**, 453-463.

- Hernandez, A.E., Kotz, S.A., Hoffman, J., Valentin, V.V., Dapretto, M. & Bookheimer, S.Y. (2004). The neural correlates of grammatical gender decisions in Spanish. *Neuroreport*, **15**, 863-866.
- Hull, R., & Vaid, J. (2006). Laterality and language experience. *Laterality*, **11**, 436-464.
- Humphreys, G. W., Evett, L. J., & Quinlan, P. T. (1990). Orthographic processing in visual word identification. *Cognitive Psychology*, **22**, 517-560.
- Humphreys, G. W., Evett, L. J., Quinlan, P. T., & Besner, D. (1987). Orthographic priming: Qualitative differences between priming from identified and unidentified primes. In M. Coltheart (Ed.), *Attention and performance XII* (pp. 201-219). Hillsdale, NJ: Erlbaum.
- Iacobini, C. (2008). Morphological typology. In K. Brown & S. Ogilvie (Eds.), *Concise encyclopedia of languages of the world* (pp. 730-735). Amsterdam, North Holland: Elsevier.
- Ibrahim, R. (2006). Morphophonemic similarity within and between languages: A factor to be considered in processing Arabic and Hebrew. *Reading & Writing*, **19**, 563-586.
- Ibrahim, R., & Eviatar, Z. (2009). Language status and hemispheric involvement in reading: Evidence from trilingual Arabic speakers

- tested in Arabic, Hebrew and English. *Neuropsychology*, **23**, 240-254.
- Ibrahim, R., Eviatar, Z., & Aharon-Peretz, J. (2002). The characteristics of Arabic orthography slow its processing. *Neuropsychology*, **16**, 322-326.
- Järvikivi, P., Pyykkönen, J., & Niemi, J. (2009). Exploiting degrees of inflectional ambiguity: Stem form and the time course of morphological processing. *Journal of Experimental Psychology: Learning Memory & Cognition*, **35**, 221-237.
- Kachru, Y. (2006). *Hindi: Vol. 12. London Oriental and African language library*. Philadelphia, PA: John Benjamins.
- Kachru, Y. (2008). Hindi-Urdu-Hindustani. In B. B. Kachru, Y. Kachru, & S. N. Sridhar (Eds.), *Language in South Asia* (pp. 81-102). Cambridge, MA: Cambridge University Press.
- Kazanina, N., Dukova-Zheleva, G., Geber, D., Kharlamov, V., & Tonciulescu, K. (2008). Decomposition into multiple morphemes during lexical access: A masked priming study of Russian nouns. *Language & Cognitive Processes*, **23**, 800-823.
- Koenig, O., Wetzel, C., & Caramazza, A. (1992). Evidence for different types of lexical representations in the cerebral hemispheres. *Cognitive Neuropsychology*, **9**, 33-45.

- Koivisto, M. (1997). Time course of semantic activation in the cerebral hemispheres. *Neuropsychologia*, **35**, 497-504.
- Kramer, R. (2007). Nonconcatenative morphology in Coptic. UC Santa Cruz: Linguistics Research Center. Retrieved December 1, 2009, from: <http://escholarship.org/uc/item/0765s94q>.
- Kumar, U., Das, T., Bapi, R. S., Padakannaya, P., Joshi, R. M., & Singh, N. C. (2009). Reading different orthographies: An fMRI study of phrase reading in Hindi-English bilinguals. *Reading & Writing*, **23**, 239-255.
- Kuo, W., Yeh, T., Duann, J., Wu, Y., Ho, L., Hung, D., Tzeng, O. J. L., & Hsieh, J. C. (2001). A left-lateralized network for reading Chinese words: A 3T fMRI study. *NeuroReport*, **12**, 3997-4001.
- Laine, M., & Koivisto, M. (1998). Lexical access to inflected words as measured by lateralized visual lexical decision. *Psychological Research: Psychologische Forschung*, **61**, 220-229.
- Laine, M., Rinne, J. O., Krause, B. J., Teräs, M., & Sipilä, H. (1999). Left hemisphere activation during processing of morphologically complex word forms in adults. *Neuroscience Letters*, **271**, 85-88.
- Laudanna, A., & Burani, C. (1985). Address mechanisms to decomposed lexical entries. *Linguistics*, **23**, 775-792.
- Lavidor, M., & Ellis, A. W. (2003). Interhemispheric integration in a split-processing model of visual word recognition. *Cortex*, **39**, 69-83.

- Lavric, A., Clapp, A., & Rastle, K. (2007). ERP evidence of morphological analysis from orthography: A masked priming study. *Journal of Cognitive Neuroscience*, **19**, 866-877.
- Lehtonen, M., Vorobyev, V. A., Hugdahl, K., Tuokkola, T., & Laine, M. (2006). Neural correlates of morphological decomposition in a morphologically rich language: An fMRI study. *Brain and Language*, **98**, 182-193.
- Leong, C. K., Wong, S., Wong, A., & Hiscock, M. (1985). Differential cerebral involvement in perceiving Chinese characters: Levels of processing approach. *Brain & Language*, **26**, 131-145.
- Libben, G., Gibson, M., Yoon, Y. B., & Sandra, D. (2003). Compound fracture: The role of semantic transparency and morphological headedness. *Brain & Language*, **84**, 26-43.
- Longtin, C. M., & Meunier, F. (2005). Morphological decomposition in early visual word processing. *Journal of Memory & Language*, **53**, 26-41.
- Longtin, C. M., Seguí, J., & Hallé, P. A. (2003). Morphological priming without morphological relationship. *Language & Cognitive Processes*, **18**, 313-334.
- Lukatela, G., & Turvey, M. T. (1987). Loci of phonological effects in the lexical access of words written in a shallow orthography. *Psychological Research: Psychologische Forschung*, **49**, 139-146.

- Lukatela, G., & Turvey, M. T. (1994). Visual lexical access is initially phonological: Evidence from associative priming by words, homophones, and pseudohomophones. *Journal of Experimental Psychology: General*, **123**, 107-128.
- Lupker, S. J., Brown, P., & Colombo, L. (1997). Strategic control in a naming task: Changing routes or changing deadlines? *Journal of Experimental Psychology: Learning, Memory & Cognition*, **23**, 570-590.
- Maass, A., & Russo, A. (2003). Directional bias in the mental representation of spatial events: Nature or culture? *Psychological Science*, **14**, 296-301.
- Mainy, N., Jung, J., Baciú, M., Kahane, P., Schöndorff, B., Minotti, L., Hoffmann, D., Bertrand, O., Lachaux, J. P. (2007). Cortical dynamics of word recognition. *Human Brain Mapping*, **29**, 1215-1230.
- Marangolo P., Incoccia, C., Pizzamiglio, L., Sabatini, U., Castriota-Scanderbeg, A., & Burani, C. (2003). *Journal of Cognitive Neuroscience*, **15**, 364-371.
- Marangolo P., Piras, F., Galati, G., & Burani, C. (2004). The neural substrates of derivational morphological processing: An FRMI study. *Cortex*, **40**, 185-186.

- Marslen-Wilson, W. D., Tyler, L. K., Waksler, R., & Older, L. (1994). Morphology and meaning in the English mental lexicon. *Psychological Review*, **101**, 3-33.
- Marslen-Wilson, W. D., & Zhou, X. L. (1999). Abstractness, allomorphy and lexical architecture. *Language & Cognitive Processes*, **14**, 321-352.
- Masica, C. (1991). *Indo-Aryan languages*. Cambridge, MA: Cambridge University Press.
- Masson, M. E. J., & Isaak, M. I. (1999). Masked priming of words and nonwords in a naming task: Further evidence for a nonlexical basis for priming. *Memory & Cognition*, **27**, 399-412.
- Mathur, R. (2005). Aspects of concatenative and non-concatenative morphology of standard Hindi. *Language in India*, **4**, 1-10.
- Mathur, R. (2007). Preparation problems in developing lexical resources for computing. Paper presented at the seminar on Lexical Resources for Indian Language Computing and Processing (LRIL-2007), Mumbai, India. Retrieved October 24, 2009, from: http://tdil.mit.gov.in/april-jan-08/8.11_Preperation_Problems.pdf.
- McCormick, S. F., Rastle, K., & Davis, M.H. (2008). Is there a 'fete' in 'fetish'? Effects of orthographic opacity on morpho-orthographic

- segmentation in visual word recognition. *Journal of Memory & Language*, **2**, 307-326.
- McQueen, J. M., & Cutler, A. (1998). Morphology in word recognition. A. Spencer, & A. M. Zwicky (Eds.), *The handbook of morphology* (pp. 406-427). Oxford, UK: Blackwell.
- Melamed, F., & Zaidel, E. (1993). Language and task effects on lateralized word recognition. *Brain & Language*, **45**, 70-85.
- Melinger, A. (2001). The contribution of semantic transparency to the morphological decomposition of prefixed words. *Folia Linguistica*, **35**, 285-297.
- Meunier, F., & Longtin, C. M. (2007). Morphological decomposition and semantic integration in word processing. *Journal of Memory & Language*, **56**, 457-471.
- Miceli G., & Caramazza, A. (1988). Dissociation of inflectional and derivational morphology. *Brain & Language*, **35**, 24-65.
- Morris, J., Frank, T., Grainger, J., & Holcomb, P. J. (2007). Semantic transparency and masked morphological priming: An ERP investigation. *Psychophysiology*, **44**, 506-521.
- Moscoso del Prado Martin, F., Bertram, R., Häikiö, T., Schreuder, R., & Baayen, R. H. (2004). Morphological family size in a morphologically rich language: The case of Finnish compared with

- Dutch and Hebrew. *Journal of Experimental Psychology: Learning Memory & Cognition*, **30**, 1271-1278.
- Moscoso del Prado Martin, F., Deutsch, A., Frost, R., Schreuder, R., de Jong, N. H., & Baayen, R. H. (2005). Changing places: A cross-language perspective on frequency and family size in Dutch and Hebrew. *Journal of Memory & Language*, **53**, 496-512.
- Mumtaz, S., & Humphreys, G. W. (2002). The effect of Urdu vocabulary size on the acquisition of single word reading in English. *Educational Psychology*, **22**, 165-190.
- Murrell, G. A., & Morton, J. (1974). Word recognition and morphemic structure. *Journal of Experimental Psychology*, **102**, 963-968.
- Nachshon, I. (1985). Directional preferences in perception of visual stimuli. *International Journal of Neuroscience*, **25**, 161-174.
- Nachshon, I., Argaman, E., & Luria, A. (1999). Effects of directional habits and handedness on aesthetic preference for left and right profiles. *Journal of Cross-Cultural Psychology*, **30**, 106-114.
- Nevins, A., Dillon, B., Malhotra, S., & Phillips, C. (2007). The role of feature-number and feature-type in processing Hindi verb agreement violations. *Brain Research*, **1164**, 81-94.
- Niemi, J., Laine, M., & Tuominen, J. (1994). Cognitive morphology in Finnish: Foundations of a new model. *Language & Cognitive Processes*, **9**, 423-446.

- Obler, L. K., Zatorre, R. J., Galloway, L., & Vaid, J. (1982). Cerebral lateralization in bilinguals: Methodological issues. *Brain & Language*, **15**, 40-54.
- Perea, M., & Gotor, A. (1997). Associative and semantic priming effects occur at very short SOAs in lexical decision and naming. *Cognition*, **62**, 223-240.
- Plaut, D. C., & Gonnerman, L. M. (2000). Are non-semantic morphological effects incompatible with a distributed connectionist approach to lexical processing? *Language & Cognitive Processes*, **15**, 445-485.
- Prakash, P., & Joshi, R. M. (1995). Orthography and reading in Kannada: A Dravidian language. In I. Taylor & D. R. Olsen (Eds.), *Scripts and literacy: Reading and learning to read alphabets, syllabaries and characters* (pp. 95-108). Dordrecht, The Netherlands: Kluwer.
- Proverbio, A. M., Vecchi, L., & Zani, A. From orthography to phonetics: ERP measures of grapheme-to-phoneme conversion mechanisms in reading. *Journal of Cognitive Neuroscience*, **16**, 301 -3317.
- Prunet, J. F., Beland, A., & Idrissi, A. (2000). The mental representation of Semitic words. *Linguistic Inquiry*, **31**, 609-648.

- Pylkkänen, L., Feintuch, S., Hopkins, E., & Marantz, A. (2004). Neural correlates of the effects of morphological family frequency and family size: An MEG study. *Cognition*, **91**, B35-B45.
- Rastle, K., & Davis, M. H. (2008). Morphological decomposition based on the analysis of orthography. *Language & Cognitive Processes*, **23**, 942-971.
- Rastle, K., Davis, M. H., Marslen-Wilson, W. D., & Tyler, L. K. (2000). Morphological and semantic effects in visual word recognition: A time-course study. *Language & Cognitive Processes*, **15**, 507-537.
- Rastle, K., Davis, M. H., & New, B. (2004). The broth in my brother's brothel: Morpho-orthographic segmentation in visual word recognition. *Psychonomic Bulletin & Review*, **11**, 1090-1098.
- Rao, C., & Vaid, J. (2009, June). *Hemispheric asymmetry in Hindi vs. Urdu morphological processing: An orthography-based account*. Poster presented at the conference on Theoretical and Experimental Neuropsychology (TENNET), Montreal, Canada.
- Rao, C., Vaid, J., Srinivasan, N., & Chen, H-C. (2009). *Orthographic characteristics speed Hindi word naming but slow Urdu naming: Evidence from Hindi/Urdu biliterates*. Manuscript submitted for publication.

- Rodriguez-Fornells, A., Münte, T. F., & Clahsen, H. (2002). Morphological priming in Spanish verb forms: An ERP repetition priming study. *Journal of Cognitive Neuroscience*, **14**, 443-454.
- Roman, G., & Pavard, B. (1987). A comparative study: How we read in Arabic and French. In J. K. O'Regan & A. Lévy-Schoen (Eds.), *Eye movements: From physiology to cognition* (pp. 431-440). Amsterdam, North Holland: Elsevier.
- Rueckl, J. G., & Aicher, K. A. (2008). Are CORNER and BROTHER morphologically complex? Not in the long term. *Language & Cognitive Processes*, **23**, 972-1001.
- Rueckl, J. G., & Gantalucci, B. (2005). The locus and time course of long-term morphological priming. *Language & Cognitive Processes*, **20**, 115-138.
- Rueckl, J. G., Mikolinski, M., Raveh, M., Miner, C. S., & Mars, F. (1997). Morphological priming, fragment completion, and connectionist networks. *Journal of Memory & Language*, **36**, 382-405.
- Rueckl, J. G., & Raveh, M. (1999). The influence of morphological regularities on the dynamics of a connectionist network. *Brain & Language*, **68**, 110-117.
- Sakurai, Y., Toshimitsu, M., Iwata, M., Watanabe, T., Ishikawa, T., Takeda, K., & Kanazawa, I. (1992). Kanji word reading process

- analyzed by positron emission tomography. *NeuroReport*, **3**, 445-448.
- Sandra, D. (1990). On the representation and processing of compound words: Automatic access to constituent morphemes does not occur. *Quarterly Journal of Experimental Psychology Section-A*, **42**, 529-567.
- Sapir, E. (1921). *Language: An introduction to the study of speech*. New York: Harcourt Brace. URL: www.bartleby.com/186/.
- Sasanuma, S., Itoh, M., Mori, K., & Kobayashi, K. (1977). Tachistoscopic recognition of Kana and Kanji words. *Neuropsychologia*, **15**, 547-553.
- Sasanuma, S., Itoh, M., Kobayashi, & K. Mori, K. (1977). The nature of the task-stimulus interaction in the tachistoscopic recognition of Kana and Kanji words. *Brain & Language*, **9**, 298-306.
- Schreuder, R., & Baayen, R. H. (1995). Modeling morphological processing. In L. B. Feldman (Ed.), *Morphological aspects of language processing* (pp. 131-154). Hillsdale, NJ: Erlbaum.
- Schreuder, R., & Baayen, R. H. (1997). How complex simplex words can be. *Journal of Memory & Language*, **37**, 118-139.
- Seguí, J., & Grainger, J. (1990). The word repetition effect in masked priming. *Année Psychologique*, **90**, 345-357.

- Seidenberg, M. S., & Gonnerman, L. M. (2000). Explaining derivational morphology as the convergence of codes. *Trends in Cognitive Sciences*, **4**, 353-361.
- Sereno, J. A. (1991). Graphemic, associative, and syntactic priming effects at brief stimulus onset asynchrony in lexical decision and naming. *Journal of Experimental Psychology: Learning, Memory & Cognition*, **17**, 459-477.
- Shah, A., Baum, S., & Dwivedi, V. (2006). Neural substrates of linguistic prosody: Evidence from syntactic disambiguation in the productions of brain-damaged patients. *Brain & Language*, **96**, 78-89.
- Shillcock, R. C., & McDonald, S. A. (2005). Hemispheric division of labour in reading. *Journal of Research in Reading*, **28**, 244-257.
- Shoolman, N., & Andrews, S. (2003). Racehorses, reindeer and sparrows: Using masked priming to investigate morphological influences on compound word identification. In S. Kinoshita & S. J. Lupker (Eds.), *Masked priming: The state of the art* (pp. 241-278). Hove, UK: Psychology Press.
- Simpson, G. B., & Burgess, C. (1985). Activation and selection processes in the recognition of ambiguous words. *Journal of Experimental Psychology: Human Perception & Performance*, **11**, 28-39.

- Singh, R., & Agnihotri, R.K. (1997). *Hindi morphology: A word based description*. Delhi, Motilal Banarsidass.
- Stanners, R. F., Neiser, J. J., Hernon, W. P., & Hall, R. (1979). Memory representation for morphologically related words. *Journal of Verbal Learning & Verbal Behavior*, **18**, 399-412.
- Steele, R. G. D., & Torrey, J. H. (1980). *Principles and procedures of statistics* (2nd ed.). New York: McGraw-Hill.
- Stief, V., & Schweinberger, S. R. (1999) Hemisphere asymmetry in repetitive priming and associative priming. *Zeitschrift für Experimentelle Psychologie*, **46**, 265-274.
- Stolz, J. A., & Feldman, L. B. (1995). The role of orthographic and semantic transparency of the base morpheme in morphological processing. In L. B. Feldman (Ed.), *Morphological aspects of language processing* (pp. 109-129). Hillsdale, NJ: Erlbaum.
- Taft, M. (1979). Recognition of affixed words and the word frequency effect. *Memory & Cognition*, **7**, 263-272.
- Taft, M. (1981). Prefix stripping revisited. *Journal of Verbal Learning & Verbal Behavior*, **20**, 289-297.
- Taft, M. (1988). A morphological-decomposition model of lexical representation. *Linguistics*, **26**, 657-668.
- Taft, M., & Forster, K. I. (1975). Lexical storage and retrieval of prefixed words. *Journal of Verbal Learning & Verbal Behavior*, **14**, 638-647.

- Taft, M., & Forster, K. I. (1976). Lexical storage and retrieval of polymorphemic and polysyllabic words. *Journal of Verbal Learning & Verbal Behavior*, **15**, 607-620.
- Tarkiainen, A., Helenius, P., Hansen, P. C., Cornelissen, P.L., & Salmelin, R. (1999). Dynamics of letter string perception in the human occipitotemporal cortex. *Brain*, **122**, 2119-2131.
- Tsapkini, K., Kehayia, E., & Jarema, G. (1999). Does phonological change play a role in the recognition of derived forms across modalities? *Brain & Language*, **68**, 318-323.
- Twist, A., & Ussishkin, A. (2009). Auditory and visual lexical decision in Maltese. In B. Comrie & R. Fabri (Eds.), *Introducing Maltese linguistics: Selected papers from the 1st International Conference on Maltese Linguistics* (pp. 233-250). Amsterdam: John Benjamins.
- Tyler, L. K., Demornay-Davies, P., Anokhina, R., Longworth, C., Randall, B., & Marslen-Wilson, W. D. (2002). Dissociations in processing past tense morphology: neuropathology and behavioral studies. *Journal of Cognitive Neuroscience*, **14**, 79-94.
- Tyler, L., K., Marslen-Wilson, W. D., & Stamatakis, E. A. (2005). Differentiating lexical form, meaning and structure in the neural language system. *Proceedings of the National Academy of Sciences, U.S.A.*, **102**, 8375-8380.

- Vaid, J. (1988). Asymmetries in tachistoscopic word recognition: Scanning effects reexamined. *International Journal of Neuroscience*, **42**, 253-258.
- Vaid, J. (1995). Script directionality influences nonlinguistic performance: Evidence from Hindi and Urdu. In I. Taylor & D. Olson (Eds.), *Scripts and literacy: Reading and learning to read alphabets, syllabaries and characters* (pp. 295-310). Dordrecht: Kluwer.
- Vaid, J., & Gupta, A. (2002). Exploring word recognition in a semi-alphabetic script: The case of Devanagari. *Brain & Language*, **81**, 679-690.
- Vaid, J., Rao, C., & Chen, H-C. (2006, July). *On the psycholinguistic significance of the bar in Hindi word recognition*. Poster presented at the annual meeting of the Society for the Scientific Study of Reading, Vancouver, Canada.
- Vaid, J., Rao, C., & Chen, H-C. (2007, July). *Factors influencing word recognition in an alpha-syllabic Indic script: Evidence from Hindi*. Poster presented at the annual meeting of the Society for the Scientific Study of Reading, Prague, Czech Republic.
- Vaid, J., Rao, C., Chen, H-C., Kar, B., & Sharma, D. R. (2008a, May). *Frequency and length effects in Hindi and Urdu: Orthographic depth*

matters. Poster presented at the annual meeting of the Association for Psychological Science, Boston, USA.

Vaid, J., Rao, C., Chen, H-C., & S. Narayanan (2008b, November).

Phonological priming in Hindi and Urdu: A preliminary investigation.

Poster presented at the annual meeting of the Psychonomics Society, Chicago, USA.

Vaid, J. & Singh, M. (1989). Asymmetries in the perception of facial affect: Is there an influence of reading habits? *Neuropsychologia*, **27**, 1277-1287.

van den Bosch, A., Content, A., Daelemans, W., de Gelder, B. (1994). Measuring the complexity of writing systems. *Journal of Quantitative Linguistics*, **1**, 178-188.

Vasishth, S. (2003). *Working memory in sentence comprehension: Processing Hindi center embeddings*. New York: Garland Press.

Vasishth, S., & Lewis, R. L. (2006). Argument-head distance and processing complexity: Explaining both locality and antilocality effects. *Language*, **82**, 767-794.

Vasishth, S., Suckow, K., Lewis, R. L., & Kern, S. (2010). Short-term forgetting in sentence comprehension: Crosslinguistic evidence from head-final structures. *Language and Cognitive Processes*. Manuscript submitted for publication.

- Whitney, C. (2004). Hemisphere-specific effects in word recognition do not require hemisphere-specific modes of access. *Brain & Language*, **88**, 279-293.
- Widmann, C. S., & Morris, R. K. (2009). Phonemic representations in morphological segmentation of written English words. *The Mental Lexicon*, **4**, 194-211.
- Yamaguchi, S., Toyoda, G., Xu, J., Kobayashi, S., & Henik, A. (2002). Electroencephalographic activity in a flanker interference task using Japanese orthography. *Journal of Cognitive Neuroscience*, **14**, 971-979.
- Yang, M. J., (1999). Hemisphere differences in accessing lexical knowledge of Chinese characters. *Laterality*, **4**, 149-166.
- Yochim, B. P., Kender, R., Abeare, C., Gustafson, A., & Whitman, R. D. (2005). Semantic activation within and across the cerebral hemispheres: What's left isn't right. *Laterality*, **10**, 131-148.
- Zaidel, E. (1998). Language in the right hemisphere following callosal disconnection. In B. Stemmer & H. Whitaker (Eds.) *Handbook of neurolinguistics* (pp. 369-383). New York: Academic.
- Zwitserlood, P. (1994). The role of semantic transparency in the processing and representation of Dutch compounds. *Language & Cognitive Processes*, **9**, 341-368.

APPENDIX A: HINDI & URDU ALPHABETS WITH PHONETIC SYMBOLS

Hindi

अ	आ	इ	ई	उ	ऊ	ऋ	ए	ऐ	ओ	औ
a	ā	i	ī	u	ū	r	e	ai	o	au
[ʌ]	[aː]	[i]	[iː]	[u]	[uː]	[r]	[e]	[ɛɪ]	[o]	[ɒʊ]

क	ख	ग	घ	ङ
ka	kha	ga	gha	a
[kʌ]	[khʌ]	[gʌ]	[ghʌ]	[ŋʌ]

च	छ	ज	झ	ञ
a	ha	ja	jha	ña
[cʌ]	[chʌ]	[ʃʌ]	[ʒhʌ]	[ɲʌ]

ट	ठ	ड	ढ	ण
a	ha	a	ha	a
[tʌ]	[thʌ]	[dʌ]	[dʰʌ]	[ɳʌ]

त	थ	द	ध	न
ta	tha	da	dha	na
[tʌ]	[thʌ]	[dʌ]	[dʰʌ]	[nʌ]

प	फ	ब	भ	म
pa	pha	ba	bha	ma
[pʌ]	[phʌ]	[bʌ]	[bhʌ]	[mʌ]

य	र	ल	व	श	ष	स	ह	ळ
ya	ra	la	va	a	a	sa	ha	a
[jʌ]	[rʌ]	[lʌ]	[vʌ]	[ʃʌ]	[ʂʌ]	[sʌ]	[hʌ]	[lʌ]

Additional Consonants:

ड़

a [ɽʌ]

ढ़

ha [ɽhʌ]

Urdu

خ	ح	چ	ج	ث	ٹ	ت	پ	ب	ا
{ he }	{ e }	{ e }	{jīm}	{se}	{ e }	{te}	{pe}	{be}	{alif}
h			j	s		t	p	b	ā
[χ]	[h]	[c]	[ʃ]	[c]	[t]	[t]	[p]	[b]	[a:]
ض	ص	ش	س	ث	ز	ڑ	ر	ذ	ڈ
{zuād}	{suād}	{ īn}	{sīn}	{ba ī ze}	{ze}	{ e }	{re}	{zāl}	{ āl}
{dāl}									
z	s		s	z	z		r	z	d
[z]	[s]	[ʃ]	[s]	[z]	[z]	[t]	[r]	[z]	[d]
ط	ظ	ع	غ	ف	ق	ک	گ	ل	م
{mīm}	{lām}	{gāf}	{kāf}	{qāf}	{fe}	{ġain}	{ īn}	{zoe}	{toe}
m	l	g	k	q	f	ġ		z	t
[m]	[l]	[g]	[k]	[q]	[f]	[ɣ]	[ʕ]	[z]	[t]
ن	و	ہ	ے						
{ye}	{ ho ī he}	{wāu}	{nūn}						
y+e	h	v+o	n						
[j+e]	[h]	[v+o]	[n]						

Transcription Key: curly braces indicate letter names (applies only to Urdu); unenclosed transcriptions indicate symbols used in this dissertation; brackets indicate phonetic transcription as per IPA (2005). The following letters of the Hindi alphabet were omitted from the above chart, due to the combinatorial phonetic values of the graphemes:

अं, आः, क्ष, त्र, ज्ञ. Nasalized vowels indicated by tilde over the letter,

e.g., ã and õ.

Note on transcription source: The symbols used for phonetic transcriptions in this dissertation were adapted from the symbols used for Hindi by Vaid and Gupta (2002), and from those used for Kannada by Prakash and Joshi (1995).

APPENDIX B: PRIME-TARGET PAIRS USED IN EXPERIMENTS 1, 2 & 4

#	Tgt (H)	Fqcy (H)	Target		Phon Trans	Meaning
			Tgt (U)	Fqcy (U)		
001	बेल	4.2 (1.7)	بیل	5.7 (1.8)	bel	roll
002	गुम	5.1 (1.6)	گم	5.2 (1.8)	gum	lost
003	मह	3.1 (2.0)	مه	5.0 (2.5)	mah	moon
004	जल	6.4 (1.0)	جل	6.1 (1.6)	jal	burn
005	बन	5.2 (1.7)	بن	5.0 (2.2)	ban	be made
006	शह	3.4 (1.7)	شه	5.1 (2.3)	śah	check
007	हम	6.6 (0.7)	هم	6.0 (1.8)	ham	we
008	वर	5.5 (1.9)	ور	5.2 (2.0)	var	blessing
009	घट	3.8 (2.3)	گھٹ	5.3 (1.9)	ghaṭ	decrease
010	ठोक	4.2 (1.8)	ٹھوک	4.1 (2.1)	ṭok	hammer
011	नर	5.8 (1.6)	نر	4.3 (2.0)	nar	man
012	तल	3.9 (1.7)	تل	4.3 (2.3)	tal	bottom
013	पूछ	5.5 (1.9)	پوچھ	6.4 (1.3)	pūḥ	ask
014	आब	3.6 (2.2)	آب	6.5 (1.4)	āb	brightness
015	बल	4.9 (2.1)	بل	5.7 (2.0)	bal	strength
016	वेद	3.9 (2.6)	وید	4.5 (2.1)	ved	Vedas
017	छल	3.5 (2.0)	چھل	4.8 (2.0)	ḥal	cheat
018	देव	3.5 (2.3)	دیو	4.7 (2.3)	dev	divine being
019	बिल	4.4 (2.1)	بیل	5.5 (1.6)	bil	receipt
020	टोक	3.5 (1.7)	ٹوک	6.0 (1.4)	ṭok	scold
021	पेश	5.3 (2.0)	پیش	6.6 (0.9)	peś	present
022	पर	5.3 (2.4)	پر	5.6 (1.9)	par	wing
023	दर	4.9 (2.1)	در	6.2 (1.5)	dar	door
024	धन	5.5 (1.8)	دھن	6.0 (2.0)	dhan	wealth
025	झर	2.5 (1.5)	جھر	3.5 (1.9)	jhar	spring
026	ज़र	3.4 (2.1)	زر	5.1 (2.0)	zar	gold

Target						
#	Tgt (H)	Fqcy (H)	Tgt (U)	Fqcy (U)	Phon Trans	Meaning
027	चित	2.4 (1.8)	چیت	3.6 (2.2)	ʧit	mind
028	कोह	1.8 (1.3)	کوه	4.7 (2.2)	koh	mountain
029	सुर	3.2 (1.7)	سُر	5.6 (1.9)	sur	tune
030	दल	3.9 (2.4)	دل	3.9 (2.3)	dal	tree
031	सर	5.8 (1.9)	سر	5.8 (1.7)	sar	head
032	पक	2.4 (2.1)	پک	4.1 (1.9)	pak	ripen
033	कम	5.6 (1.9)	کم	5.9 (1.4)	kam	less
034	मोह	3.5 (2.4)	موه	4.2 (2.2)	moh	enchantment
035	सुध	2.7 (1.8)	سُده	4.2 (1.6)	sudh	sobriety
036	कर	4.5 (2.0)	کر	5.9 (1.4)	kar	do
037	पग	3.2 (2.1)	پگ	2.7 (1.8)	pag	leg
038	चुन	3.9 (2.1)	چُن	5.2 (1.7)	ʧun	choose
039	इन	4.3 (2.8)	ان	6.0 (1.3)	in	these
040	बक	3.6 (1.9)	بک	5.3 (2.3)	bak	empty talk
041	बाल	5.8 (2.1)	بال	6.4 (1.0)	bāl	hair
042	सुन	5.7 (1.5)	سُن	6.5 (1.4)	sun	listen
043	मर	4.7 (2.4)	مر	6.0 (1.7)	mar	die
044	जन	4.5 (2.0)	جن	4.1 (1.7)	jan	people
045	गिर	4.2 (2.5)	گر	5.8 (2.1)	gir	fall
046	हर	5.7 (1.9)	هر	6.4 (1.0)	har	every
047	सब	6.4 (1.0)	سب	6.8 (0.4)	sab	all
048	दब	5.0 (2.1)	دب	4.8 (2.3)	dab	be suppressed
049	भाग	6.4 (0.8)	بھاگ	6.4 (1.0)	bhāg	run
050	पत	2.8 (2.0)	پت	3.2 (2.2)	pat	leaf
051	दम	5.2 (2.0)	دم	5.9 (1.2)	dam	breath
052	नाग	4.1 (1.7)	ناگ	3.8 (2.5)	nāg	serpent

#	Tgt (H)	Fqcy (H)	Target		Phon Trans	Meaning
			Tgt (U)	Fqcy (U)		
053	पाप	6.3 (0.8)	پاپ	5.9 (1.8)	pāp	sin
054	आस	6.0 (1.2)	آس	5.6 (1.6)	ās	hope
055	जुट	4.5 (1.3)	جٹ	5.3 (2.1)	juṭ	be recruited
056	लाल	6.3 (1.0)	لال	5.5 (2.5)	lāl	red
057	आप	6.8 (0.4)	آپ	7.0 (0.0)	āp	you (pl.)
058	मल	4.0 (2.3)	مل	5.9 (1.4)	mal	rub
059	सज	4.0 (2.3)	سج	4.3 (2.3)	saj	decorate
060	मोर	5.5 (1.9)	مور	4.8 (2.4)	mor	peacock
061	पल	5.3 (2.1)	پل	5.3 (2.1)	pal	moment
062	टिक	4.0 (2.0)	ٹیک	3.7 (2.4)	ṭik	stay
063	अब	6.4 (1.4)	اب	6.6 (0.9)	ab	now
064	लड़	5.2 (2.0)	لڑ	4.8 (2.0)	laṛ	fight
065	चर	2.8 (2.0)	چر	3.0 (2.1)	ṭar	graze
066	कट	3.2 (2.2)	کٹ	5.1 (1.9)	kaṭ	cut
067	बच	5.5 (1.9)	بچ	5.5 (1.5)	ba□	save
068	लग	5.2 (2.0)	لگ	6.3 (1.1)	lag	engage
069	इस	6.5 (1.4)	اس	6.5 (0.8)	is	this
070	तन	5.8 (1.9)	تن	6.2 (1.6)	tan	body
071	राज	5.8 (1.7)	راج	5.5 (1.4)	rāj	rule
072	शोर	6.6 (0.5)	شور	6.5 (1.4)	śor	noise
073	झट	4.7 (2.1)	جھٹ	6.1 (1.1)	jhaṭ	instantaneous
074	बह	3.8 (2.2)	بہ	6.0 (1.7)	bah	flow
075	तार	5.8 (1.7)	تار	5.3 (1.9)	tār	wire
076	गुन	4.2 (2.3)	گن	5.2 (2.1)	gun	quality
077	भर	5.3 (2.1)	بھر	6.0 (1.4)	bhar	fill
078	पट	2.7 (1.0)	پٹ	4.8 (1.9)	paṭ	fabric

Morphological Prime

#	Tgt (H)	Fqcy (H)	Tgt (U)	Fqcy (U)	Phon Trans	Meaning
001	बेलना	4.5 (2.3)	بیلنا	5.6 (1.6)	belnā	to roll (e.g., pastry)
002	गुमराह	5.7 (1.8)	گمراہ	6.5 (1.0)	gumrāh	secret
003	महताब	5.8 (1.8)	مہتاب	6.6 (0.8)	mahtāb	moonlight
004	जलता	5.4 (1.8)	جلتا	6.2 (1.9)	jaltā	burning
005	बनवा	3.5 (2.1)	بنوا	4.0 (2.3)	banvā	cause to be made
006	शहमात	2.9 (1.8)	شہ مات	2.6 (2.0)	śahmāt	checkmate
007	हमदम	5.5 (2.1)	ہمدم	6.6 (0.7)	hamdam	soulmate
008	वरदान	5.6 (1.9)	وردان	5.5 (2.3)	vardān	boon
009	घटबढ़	3.7 (2.7)	گھٹ بڑھ	4.9 (1.6)	ghaṭbarh	fluctuation
010	ठोकते	4.0 (1.9)	ٹھوکتے	4.2 (1.5)	ṭhokte	hammering
011	नरलोक	3.8 (2.2)	نرلوك	4.5 (2.4)	narlok	world of man
012	तलछट	2.8 (1.6)	تل چھٹ	4.0 (2.0)	tal□haṭ	dregs
013	पूछताछ	6.8 (0.4)	پوچھتاچھ	5.8 (1.8)	pū□htā□h	inquiry
014	आबरू	5.0 (1.8)	آبرو	6.1 (1.7)	ābrū	honor
015	बलवान	4.5 (1.9)	بلوان	4.3 (2.2)	balvān	muscle-man
016	वेदपाठ	3.3 (1.9)	وید پاٹھ	3.0 (1.9)	vedpāṭh	sacred teachings
017	छलना	2.7 (1.4)	چھلنا	5.1 (1.9)	□halnā	to cheat
018	देवता	5.0 (2.1)	دیوتا	5.9 (1.1)	devtā	demigod
019	बिल्टी	2.5 (2.3)	بیلٹی	2.3 (1.6)	bilṭī	ticket
020	टोकने	3.7 (1.4)	ٹوکنے	5.0 (1.5)	ṭokne	to scold
021	पेशकश	5.8 (1.4)	پیشکش	6.7 (0.6)	peśkaś	presentation
022	परवाज़	4.8 (2.2)	پر واز	6.3 (1.5)	parvāz	winged creature
023	दरगाह	5.6 (1.6)	درگاہ	6.1 (1.8)	dargāh	shrine
024	धनवान	5.7 (1.7)	دھنوان	4.9 (2.0)	dhanvān	wealthy man
025	झरना	4.5 (2.3)	جھرنا	5.2 (2.3)	jharnā	cascade
026	ज़रदोज़	2.8 (2.4)	زردوز	3.9 (1.9)	zardoz	gold embroidery

Morphological Prime

#	Tgt (H)	Fqcy (H)	Tgt (U)	Fqcy (U)	Phon Trans	Meaning
027	चितचोर	2.3 (1.5)	چیت چور	3.2 (2.2)	ʈitʈor	one who steals peace of mind
028	कोहनी	3.7 (1.9)	کونہی	4.5 (1.7)	kohnī	elbow
029	सुरताल	3.4 (1.8)	سُرتال	4.3 (2.2)	surtāl	tune & rhythm
030	दलदल	3.8 (2.3)	دل دل	4.5 (2.4)	daldal	swamp
031	सरदार	4.5 (1.9)	سردار	6.0 (2.0)	sardār	headman
032	पकने	4.4 (2.4)	پکنے	4.3 (2.2)	pakne	to ripen
033	कमज़ोर	5.5 (1.9)	کمزور	6.4 (0.9)	kamzor	weak
034	मोहनी	3.2 (2.2)	مونہی	4.3 (1.8)	mohnī	enchantress
035	सुधबुध	2.2 (1.3)	سده بده	4.7 (1.6)	sudhbudh	wits
036	करनी	3.2 (2.0)	کرنی	4.6 (2.1)	karnī	action
037	पगहा	2.0 (1.7)	پگھا	2.3 (1.9)	paghā	leash
038	चुनकर	4.3 (2.1)	چنکر	5.1 (2.3)	ʈunkar	having chosen
039	इनके	4.8 (2.7)	انکے	5.5 (1.8)	inke	their
040	बकवास	6.0 (1.2)	بکواس	6.8 (0.6)	bakvās	nonsense
041	बालपन	3.2 (1.8)	بال پن	4.2 (2.4)	bālpan	childhood
042	सुनकर	5.7 (1.4)	سن کر	6.4 (1.4)	sunkar	having listened
043	मरते	5.5 (1.6)	مرتے	6.7 (1.1)	marte	dying
044	जनता	5.8 (1.7)	جنتا	5.2 (1.8)	jantā	populace
045	गिरता	4.6 (2.0)	گرتا	6.5 (1.0)	girtā	falling
046	हरदम	5.9 (1.0)	ہردم	6.9 (0.3)	hardam	forever
047	सबसे	6.2 (1.5)	سب سے	6.4 (1.1)	sabse	more than anything
048	दबना	4.8 (2.0)	دبنا	5.8 (1.6)	dabnā	to be suppressed
049	भागदौड़	5.8 (1.8)	بھاگ دوڑ	6.2 (1.5)	bhāgdaur	bustle
050	पतझड़	4.9 (1.7)	پتجھڑ	5.2 (1.7)	patjhar	autumn
051	दमदार	5.8 (1.8)	دمدار	5.9 (1.1)	damdār	vigorous
052	नागराज	3.5 (1.8)	ناگ راج	3.2 (2.0)	nāgrāj	cobra

Morphological Prime

#	Tgt (H)	Fqcy (H)	Tgt (U)	Fqcy (U)	Phon Trans	Meaning
053	पापमय	2.3 (1.9)	پاپم	3.0 (2.5)	pāpmay	sinful
054	आसरा	5.6 (1.2)	آسرا	4.5 (2.1)	āsra	shelter
055	जुटना	4.4 (2.1)	جٹنا	3.8 (2.3)	juṭnā	to be recruited
056	लालड़ी	2.0 (1.9)	لالڑی	3.2 (2.6)	lālīrī	ruby
057	आपसी	6.0 (1.5)	آپسی	5.8 (1.5)	āpsī	neighborhood
058	मलना	4.5 (1.9)	ملنا	6.2 (1.7)	malnā	to rub
059	सजके	2.8 (2.0)	سج کے	5.6 (2.1)	sajke	having been decorated
060	मोरनी	5.3 (1.8)	مورنی	4.9 (2.5)	mornī	peahen
061	पलभर	5.8 (1.9)	پل بھر	5.9 (1.4)	palbhar	momentary
062	टिकता	5.1 (1.4)	ٹکاتا	4.7 (2.1)	ṭiktā	staying
063	अबतब	5.5 (1.8)	اب تب	5.4 (1.9)	abtab	now & then
064	लड़ना	6.4 (1.0)	لڑنا	5.5 (2.4)	laṛnā	to fight
065	चरनी	2.8 (1.9)	چرنی	2.5 (2.0)	ṛarnī	fodder
066	कटवा	3.0 (1.8)	کٹوا	4.2 (2.1)	kaṭvā	cause to be cut
067	बचके	6.0 (1.7)	بچ کے	6.4 (1.4)	baṭke	having been saved
068	लगना	6.4 (0.7)	لگنا	6.5 (0.9)	lagnā	to engage
069	इसका	6.2 (1.1)	اسکا	6.5 (1.0)	iskā	belonging to this
070	तनमन	6.0 (1.6)	تن من	5.6 (1.4)	tanman	body & soul
071	राजपूत	6.3 (1.7)	راج پوت	4.6 (2.2)	rājput	member of a noble clan
072	शोरगुल	6.4 (1.0)	شور گُل	7.0 (0.0)	śorḡul	hubbub
073	झटपट	5.1 (2.2)	جھٹ پٹ	6.6 (1.0)	jhaṭpaṭ	instantly
074	बहता	5.5 (2.0)	بہتا	6.5 (1.1)	bahtā	flowing
075	तारघर	5.4 (2.1)	تار گھر	3.9 (2.3)	tārghar	telegraph office
076	गुनगान	4.2 (2.4)	گُنگان	3.9 (2.0)	gungān	praise
077	भरती	5.7 (1.8)	بھرتی	5.5 (2.1)	bhartī	filling
078	पटकार	2.2 (1.5)	پٹکار	3.9 (2.5)	paṭkār	weaver

Form Prime

#	Tgt (H)	Fqcy (H)	Tgt (U)	Fqcy (U)	Phon Trans	Meaning
001	बेलचा	2.9 (1.6)	تیلچا	3.6 (2.2)	bel̥a	shovel
002	गुमटा	1.8 (1.6)	گمٹا	2.3 (2.3)	gumṭa	bump (bruise)
003	महका	5.4 (1.8)	مہکا	5.8 (1.3)	mahkā	fragrant
004	जलवा	5.4 (2.0)	جلوا	6.0 (1.1)	jalvā	flame
005	बनसी	3.4 (2.0)	بنسی	4.3 (1.9)	bansī	flute
006	शहरी	6.1 (1.7)	شہری	6.4 (1.2)	śahrī	citified
007	हमज़ा	2.8 (1.9)	ہمزہ	4.8 (2.4)	hamzā	letter in Urdu alphabet
008	वरदी	5.6 (1.6)	وردی	5.9 (1.6)	vardī	uniform
009	घटवार	1.6 (1.0)	گھٹوار	3.1 (2.3)	ghaṭvār	boatman
010	ठोकवा	1.9 (1.3)	ٹھوکوا	2.8 (1.9)	ṭhokvā	thick cake
011	नरमी	5.3 (1.8)	نرمی	6.5 (0.9)	narmī	softness
012	तलवार	6.3 (1.4)	تلوار	6.2 (1.9)	talvār	sword
013	पूछरी	1.8 (1.7)	پوچھری	2.8 (2.3)	pū̃hrī	little tail
014	आबनूस	1.8 (1.7)	آبنوس	3.2 (2.3)	ābnūs	dew
015	बलगम	4.3 (2.3)	بلغم	4.0 (2.2)	balgam	mucus
016	वेदना	2.8 (1.6)	ویدنا	3.2 (1.7)	vednā	agony
017	छलका	3.5 (1.9)	چھلکا	4.8 (1.9)	ḥalkā	cause to spill
018	देवदार	2.9 (2.3)	دیودار	4.9 (1.9)	devdār	cedar
019	बिल्कुल	6.3 (0.9)	بالکل	6.4 (1.4)	bilkul	absolutely
020	टोकरी	4.8 (2.0)	ٹوکری	5.3 (1.9)	ṭokrī	basket
021	पेशवा	4.0 (2.0)	پیشوا	5.4 (2.3)	peśvā	chieftain
022	परबत	4.1 (2.0)	پرہت	4.7 (2.1)	parbat	mountain
023	दरजी	4.6 (1.9)	درزی	5.5 (2.0)	darzī	tailor
024	धनदा	3.8 (1.9)	دھندا	4.2 (2.2)	dhandā	business
025	झरबेर	1.7 (1.4)	جھربیر	2.9 (1.6)	jharber	strawberry
026	ज़रदा	3.8 (2.2)	زرده	5.2 (1.7)	zardā	tobacco

Form Prime

#	Tgt (H)	Fqcy (H)	Tgt (U)	Fqcy (U)	Phon Trans	Meaning
027	चितला	1.8 (1.5)	چٲٲا	2.1 (0.9)	ṡtlā	speckled
028	कोहरा	4.5 (1.6)	کھرا	4.5 (2.1)	kohrā	fog
029	सुरमा	2.4 (1.4)	سورما	4.4 (2.0)	surmā	kohl
030	दलहन	4.4 (1.9)	دٲهن	5.4 (1.8)	dalhan	lentils
031	सरदी	4.6 (1.9)	سردي	5.7 (1.8)	sardī	winter
032	पकड़ा	4.8 (1.5)	پکڑا	5.7 (1.7)	pakṛā	caught
033	कमरा	5.7 (1.8)	کمرآ	6.0 (1.2)	kamrā	room
034	मोहलत	3.8 (1.7)	مہلت	6.1 (1.0)	mohlat	reprieve
035	सुधरा	4.2 (2.2)	سودھرا	4.0 (2.5)	sudhrā	reformed
036	करवट	4.3 (1.7)	کروٹ	5.5 (1.4)	karvaṭ	side
037	पगड़ी	3.6 (1.9)	پگڑی	4.6 (1.9)	pagṛī	turban
038	चुनरी	3.4 (2.1)	چنری	3.9 (2.5)	ṡunrī	scarf
039	इनसान	6.4 (1.2)	انسان	6.3 (1.7)	insān	human being
040	बकरी	6.6 (0.9)	کبری	6.4 (1.4)	bakrī	goat
041	बालटी	6.6 (0.9)	بالٹی	6.5 (1.3)	bālṭī	bucket
042	सुनसान	5.7 (0.9)	سُنسان	5.6 (1.7)	sunsān	deserted
043	मरज़ी	5.8 (1.9)	مرضی	6.3 (1.5)	marzī	will
044	जनरल	5.9 (1.3)	جنرل	4.5 (2.1)	janral	General
045	गिरवी	5.1 (1.4)	گروی	4.7 (1.9)	girvī	mortgaged
046	हरजा	3.4 (1.7)	هرجآ	3.9 (2.4)	harjā	loss
047	सबज़ी	6.1 (1.3)	سبزی	6.2 (1.8)	sabzī	vegetable
048	दबका	2.7 (1.5)	دٲکٲ	2.5 (1.5)	dabkā	gold wire
049	भागवान	5.2 (1.9)	گھاگوان	2.2 (1.8)	bhāgvān	wife
050	पतला	6.1 (1.0)	پٲلا	5.8 (1.9)	patlā	slender
051	दमड़ी	3.1 (1.9)	دمڑی	2.2 (1.1)	damṛī	penny
052	नागरिक	6.2 (1.7)	ناگړک	4.8 (2.3)	nāgrik	citizen

Form Prime

#	Tgt (H)	Fqcy (H)	Tgt (U)	Fqcy (U)	Phon Trans	Meaning
053	पापड़ी	3.1 (2.3)	پاپڑی	4.0 (2.1)	pāprī	thin, crisp cake
054	आसपास	6.8 (0.4)	آسپاس	6.3 (1.1)	āspās	nearby
055	जुटली	1.6 (1.0)	جٹلی	2.5 (2.0)	juṭlī	tuft of hair
056	लालटेन	5.0 (1.7)	لاٹین	6.1 (1.3)	lālṭen	lantern
057	आपदा	4.6 (2.0)	آپدا	4.5 (2.5)	āpdā	adversity
058	मलमल	4.5 (2.0)	ملل	4.1 (2.4)	malmal	velvet
059	सजनी	4.3 (2.1)	سجنی	4.3 (2.3)	sajnī	sweetheart (f.)
060	मोरचा	4.4 (1.7)	مورچا	4.6 (1.8)	morṭā	protest march
061	पलटन	4.0 (2.0)	پلٹن	4.5 (2.1)	palṭan	battalion
062	टिकली	2.9 (2.3)	ٹیکلی	2.2 (1.9)	ṭiklī	small cake
063	अबला	4.2 (2.2)	ابلا	4.2 (2.3)	ablā	powerless (f.)
064	लड़का	6.9 (0.3)	لڑکا	6.9 (0.3)	laṛkā	boy
065	चरबी	4.8 (2.0)	چربی	4.8 (2.1)	ṭarbī	fat
066	कटरा	4.2 (2.2)	کٹرا	5.0 (1.8)	kaṭrā	crossroads
067	बचपन	6.5 (1.0)	بچپن	6.7 (0.9)	baṭpan	childhood
068	लगभग	6.6 (1.1)	لگ بھگ	6.2 (1.5)	lagbhag	approximate
069	इसपात	4.4 (2.3)	اسپات	3.5 (2.0)	ispāt	steel
070	तनहा	6.8 (0.6)	تنہا	6.9 (0.3)	tanhā	solitary
071	राजमा	3.5 (1.6)	راجما	4.3 (2.0)	rājmā	red kidney bean
072	शोरबा	3.1 (2.3)	شوربا	5.9 (1.2)	śorbā	soup
073	झटका	5.8 (1.1)	جھٹکا	5.9 (1.3)	jhaṭkā	jerk
074	बहरा	5.0 (1.5)	بہرا	5.7 (1.1)	bahrā	deaf
075	तारपीन	2.8 (1.8)	تارپین	4.9 (1.9)	tārpīn	turpentine
076	गुनगुन	3.6 (1.6)	گنگن	5.0 (1.8)	gungun	humming
077	भरकम	5.0 (2.3)	بھرکم	4.8 (2.1)	bharkam	weighty
078	पटरी	5.5 (1.1)	پٹری	5.2 (2.2)	paṭrī	rail

Control Prime

#	Tgt (H)	Fqcy (H)	Tgt (U)	Fqcy (U)	Phon Trans	Meaning
001	सेकते	4.6 (2.0)	سیک تے	4.1 (1.4)	sekte	roasting
002	रागनी	3.4 (1.9)	راڳنی	5.5 (1.6)	rāgnī	minor melody
003	पड़ना	5.4 (1.8)	پڑنا	5.9 (1.6)	paṛnā	to fall within
004	फावड़ा	4.7 (1.7)	پھاوڑا	5.2 (1.7)	phāvrā	spade
005	खटमल	4.4 (2.5)	کھٹل	5.2 (2.0)	khaṭmal	bedbug
006	तिरछी	4.5 (2.2)	ترجھی	4.9 (1.5)	tirḥī	twisted
007	रचना	5.1 (2.2)	رچنا	4.7 (1.5)	raḥnā	creation
008	पुरज़ा	4.8 (2.4)	پُرزه	5.2 (1.6)	purzā	body
009	मुखड़ा	4.6 (2.4)	مکھڑا	5.6 (1.3)	mukhrā	face
010	सूचना	6.2 (1.5)	سوچنا	6.1 (1.6)	sūḥnā	bulletin
011	बदला	6.1 (1.3)	بدلا	5.8 (1.9)	badlā	revenge
012	रूठके	5.4 (1.9)	روٹھے	5.3 (2.1)	rūṭhke	having become cross
013	खानदान	6.5 (1.1)	خانداں	6.5 (1.0)	ḵhāndān	dynasty
014	लहसुन	4.8 (1.7)	لہسن	5.4 (2.0)	lahsun	garlic
015	उठने	6.3 (1.2)	اُٹھنے	6.4 (1.1)	uṭhne	to rise
016	ग़फ़लत	5.2 (1.7)	غفلت	6.8 (0.4)	ḡaflat	carelessness
017	गुठली	2.3 (1.8)	گھٹلی	3.8 (2.0)	guṭhlī	pit (fruit)
018	जबड़ा	3.2 (1.7)	جبرّا	4.4 (1.9)	jabrā	jaw
019	मुजरिम	5.5 (1.3)	مجرم	6.5 (0.8)	mujrim	criminal
020	तबला	3.6 (2.0)	ٹبلہ	4.6 (2.1)	tablā	tabla
021	लौटके	4.9 (1.9)	لوٹ کے	5.2 (2.0)	lauṭke	having returned
022	दीनता	2.8 (1.7)	دین تا	3.7 (2.2)	dīntā	meekness
023	छोकरा	3.6 (2.3)	چھوکرّا	4.9 (2.4)	ḥokrā	lad
024	फासला	5.5 (1.6)	فاصلہ	6.3 (1.1)	fāslā	distance
025	लाइला	4.1 (2.1)	لاڈلا	5.8 (1.4)	lārlā	pet or favorite
026	बिनती	3.9 (2.1)	بنتی	4.7 (2.3)	bintī	request

Control Prime

#	Tgt (H)	Fqcy (H)	Tgt (U)	Fqcy (U)	Phon Trans	Meaning
027	कुदरत	5.7 (1.5)	قدرت	6.3 (1.5)	qudrat	nature
028	घूमना	5.5 (1.8)	گھومنا	6.6 (0.5)	ghūmnā	to roam
029	कोठरी	4.0 (2.3)	کوٹھری	5.7 (1.4)	koṭhrī	chamber
030	सोमवार	5.5 (2.0)	سوموار	5.2 (1.7)	somvār	Monday
031	दिनभर	5.2 (2.5)	دن بھر	6.2 (1.0)	dinbhar	all day
032	हिलते	3.8 (2.3)	ہلے	5.4 (1.4)	hilte	moving
033	दुगनी	4.8 (2.3)	دُگنی	4.8 (1.8)	dugnī	double
034	थकना	4.3 (2.0)	تھکنا	6.0 (1.6)	thaknā	to tire
035	जबरन	3.6 (1.9)	جبرن	5.7 (1.4)	jabran	forcibly
036	मनहूस	3.8 (2.2)	منہوس	5.7 (1.7)	manhūs	ill-omened
037	चुटकी	2.5 (1.9)	چٹکی	4.2 (2.0)	ṭuṭkī	snap (fingers)
038	मतलब	5.4 (1.8)	مطلب	6.3 (1.2)	matlab	meaning
039	शरबत	4.2 (2.3)	شربت	5.8 (1.1)	śarbat	lemonade
040	झोपड़ी	5.5 (1.7)	جھوپڑی	6.2 (1.5)	jhoprī	hut
041	धमकी	5.9 (1.5)	دھمکی	6.5 (0.9)	dhamkī	threat
042	गलती	6.5 (1.1)	غلطی	6.8 (0.6)	galtī	mistake
043	झनकार	5.2 (2.0)	جھنکار	6.4 (1.0)	inkār	jingle
044	भड़का	5.2 (1.2)	بھڑکا	4.3 (1.8)	bhaṛkā	provoke
045	तसवीर	6.8 (0.4)	تصویر	7.0 (0.0)	tasvīr	painting
046	खिड़की	6.2 (1.3)	کھڑکی	6.1 (1.5)	khīrkī	window
047	मछली	6.2 (1.2)	مچھلی	6.2 (1.3)	maḥlī	fish
048	वापसी	5.6 (1.6)	واپسی	6.5 (1.0)	vāpsī	return
049	किसका	6.9 (0.3)	کسکا	5.3 (2.3)	kiskā	whose
050	भानजी	4.8 (2.0)	بھانجی	6.2 (1.5)	bhānjī	niece
051	लालची	5.5 (1.9)	لالچی	6.2 (1.2)	lālī	greedy
052	समझा	6.1 (1.4)	سمجھا	6.5 (1.2)	samjhā	understood

Control Prime

#	Tgt (H)	Fqcy (H)	Tgt (U)	Fqcy (U)	Phon Trans	Meaning
053	लटकन	3.3 (2.0)	لٹکن	2.8 (1.9)	laṭkan	pendant
054	लोमड़ी	5.4 (1.8)	لومڑی	5.2 (2.1)	lomṛī	wolf
055	हल्का	6.4 (0.7)	ہلکا	5.0 (2.5)	halkā	light
056	छीनकर	6.4 (0.9)	چھین کر	4.9 (2.5)	ḥīnkar	snatched
057	फुर्ती	5.4 (1.8)	پُھرتی	5.1 (2.4)	phurtī	fitness
058	धरती	6.4 (1.2)	دھرتی	5.6 (2.1)	dhartī	earth
059	अनपढ़	6.1 (0.8)	انپڑھ	6.0 (1.2)	anpaṛh	illiterate
060	नापना	5.9 (1.7)	ناپنا	5.2 (2.0)	nāpnā	to measure
061	सिगरेट	6.1 (1.4)	سگریٹ	6.1 (1.9)	sigreṭ	cigarette
062	रेशमी	6.0 (1.3)	ریشمی	5.2 (2.1)	reśmī	silken
063	जानवर	6.7 (0.5)	جانور	5.9 (1.8)	jānvar	animal
064	झुमका	4.6 (2.0)	جھمکا	4.0 (2.4)	jhumkā	earring
065	निभना	3.9 (2.1)	نہنا	4.5 (2.5)	nibhnā	to abide
066	नामज़द	6.2 (1.6)	نامزد	4.6 (2.4)	nāmzad	famous
067	सेहरा	4.8 (2.0)	سہرا	6.2 (0.9)	sehrā	wreath
068	डरती	6.0 (1.8)	ڈرتی	6.6 (0.9)	ḍartī	frightened
069	हज़रत	6.2 (1.8)	حضرت	6.4 (1.0)	hazrat	respect
070	छतरी	6.0 (1.0)	چھتری	5.7 (1.4)	ḥatrī	umbrella
071	नकली	6.5 (0.8)	نقلی	5.4 (2.3)	naqlī	artificial
072	तकदीर	7.0 (0.0)	تقدیر	6.8 (0.4)	taqdīr	destiny
073	योजना	6.4 (1.1)	یोजना	4.8 (2.4)	yojnā	scheme
074	रायता	4.1 (1.7)	رائتا	5.0 (2.4)	rāyṭā	yogurt-based dish
075	कुरसी	6.1 (1.1)	کرسی	6.2 (1.5)	kursī	chair
076	पिसकर	4.5 (2.0)	پس کر	4.8 (2.1)	piskar	ground
077	गहना	5.4 (1.8)	گہنا	5.1 (1.8)	gahnā	jewel
078	बिजली	6.5 (1.4)	بجلی	6.4 (1.6)	bijlī	lightning

APPENDIX C: PRIME-TARGET PAIRS USED IN EXPERIMENTS 3 & 5

#	Tgt (H)	Fqcy (H)	Target		Phon Trans	Meaning
			Tgt (U)	Fqcy (U)		
001	भेजके	5.8 (1.4)	بھیج کے	5.8 (1.8)	bhejke	having sent
002	ठुकने	3.4 (1.9)	ٹھوکنے	5.6 (1.4)	ṭhukne	to be hammered
003	लिटवा	2.2 (1.6)	لٹوا	3.6 (1.9)	liṭvā	cause to lie down
004	टलवा	2.4 (1.7)	ٹلوا	3.2 (2.2)	ṭalvā	cause to be delayed
005	खाया	3.1 (2.0)	کھوایا	2.8 (2.0)	khavāyā	caused to eat
006	लचका	4.1 (1.8)	لچکا	5.0 (1.6)	laṭkā	bend
007	छिड़ता	4.4 (2.2)	چھڑتا	5.8 (1.3)	ḥhīṛtā	being touched
008	चलने	6.2 (1.1)	چلنے	5.9 (1.8)	ḥalne	to walk
009	जुतना	2.5 (2.1)	جوتنا	2.8 (1.3)	jutnā	to be ploughed
010	गवाया	4.2 (1.9)	گوا یا	5.2 (2.1)	gavāyā	caused to sing
011	झेलते	4.5 (1.9)	جھیلے	5.3 (1.5)	jhelte	enduring
012	नुचवा	3.2 (1.8)	نچھوا	3.7 (2.3)	nuṭvā	cause to be scratched
013	फिरता	4.9 (1.6)	پھرتا	6.2 (1.1)	phirtā	roving
014	छोड़के	4.8 (2.0)	چھوڑ کے	6.2 (1.1)	ḥhoṛke	having left
015	जुड़ता	4.3 (1.8)	جڑتا	5.3 (1.7)	jurtā	joining
016	चाटते	3.3 (1.3)	چاٹتے	5.2 (1.9)	ḥātte	licking
017	दिखना	5.4 (2.1)	دیکھنا	6.0 (1.5)	dikhnā	to be seen
018	मुड़ना	5.1 (1.9)	مڑنا	6.1 (1.6)	muṛnā	to turn
019	लिखवा	4.1 (2.4)	لکھوا	4.3 (2.0)	likhvā	cause to write
020	रुकवा	3.2 (2.1)	رکوا	3.3 (2.2)	rukṽā	cause to stop
021	मरके	3.5 (2.2)	مر کے	5.6 (1.6)	marke	having died
022	तुड़वा	2.0 (1.0)	ٹوڑوا	3.3 (2.1)	tuṛvā	cause to break
023	गुदना	2.2 (1.5)	گدنا	2.8 (1.7)	gudnā	to be etched
024	खुदवा	2.3 (1.7)	کھدوا	2.9 (1.5)	khudvā	cause to dig

Target						
#	Tgt (H)	Fqcy (H)	Tgt (U)	Fqcy (U)	Phon Trans	Meaning
025	सुलवा	2.6 (2.0)	سُلوا	3.5 (2.1)	sulvā	cause to put to sleep
026	दूसना	4.2 (2.0)	دُھوسنا	3.8 (2.2)	ṭhūsna	to stuff
027	भोगने	4.2 (2.0)	بھوگنے	4.8 (2.4)	bhogne	to experience
028	लुभाया	5.1 (1.9)	لُبھایا	5.6 (1.7)	lubhāyā	coveted
029	दिलवा	3.0 (1.7)	دِلوا	4.5 (2.5)	dilvā	cause to be given
030	डाका	4.4 (2.1)	ڈاکا	6.1 (1.4)	ḍākā	bandit attack
031	फटना	4.8 (1.9)	پھٹنا	5.9 (1.6)	phaṭnā	to tear
032	सिलना	4.8 (2.1)	سِلنا	4.0 (2.1)	silnā	to be sewn
033	धुलती	4.4 (2.3)	دھلتی	5.1 (1.9)	dhultī	being washed
034	रुलाया	6.4 (1.0)	رُلا یا	5.5 (1.9)	ruḷāyā	caused to cry
035	फुड़वा	2.3 (1.7)	پھڑوا	3.2 (1.8)	phuṛvā	cause to be burst
036	बतला	4.0 (2.5)	بتلا	4.8 (2.3)	batlā	tell
037	मोलने	2.8 (1.9)	مولنے	3.4 (2.3)	molne	to value
038	पलने	4.2 (2.0)	پالنے	4.8 (2.1)	palne	to rear
039	चुराए	6.7 (0.5)	چُرَائے	5.7 (1.5)	ḥurāe	stolen
040	बैठते	6.6 (1.4)	بیٹھتے	6.6 (0.7)	baiṭhte	sitting
041	बुलवा	2.8 (2.4)	بُلوا	5.5 (1.8)	bulvā	cause to call
042	मिलते	6.5 (0.8)	ملتے	6.7 (0.5)	milte	meeting
043	घुलता	5.2 (1.7)	گھلتا	5.7 (1.4)	ghultā	dissolving
044	खुलवा	3.5 (2.0)	کھلوا	5.9 (1.7)	khulvā	cause to open
045	पोतना	3.9 (1.7)	پوتنا	4.8 (2.1)	potnā	to daub
046	घिरना	5.3 (1.8)	گھیرنا	6.2 (1.1)	ghirnā	to be surrounded
047	घुटते	4.4 (2.0)	گھٹتے	5.9 (1.4)	ghuṭte	choking
048	बिकना	6.3 (1.4)	بیکنا	5.8 (1.5)	biknā	to be sold

Morphological Prime

#	Tgt (H)	Fqcy (H)	Tgt (U)	Fqcy (U)	Phon Trans	Meaning
001	भेजने	5.7 (2.0)	بھجینے	5.9 (1.7)	bhejne	to send
002	ठुکانے	3.5 (1.3)	ٹھوکانے	3.4 (1.9)	ṭhukāne	to cause to be hammered
003	लिटाना	5.6 (1.8)	لیٹانا	5.9 (1.9)	liṭānā	cause to lie down
004	टलना	4.7 (1.5)	ٹلنا	5.2 (1.6)	ṭalnā	to be delayed
005	खवाना	3.2 (1.9)	کھوانا	4.5 (2.5)	khavānā	cause to eat
006	लचीला	6.2 (1.5)	لچیلا	5.8 (1.3)	laṭlā	limber
007	छिड़ना	3.4 (2.3)	چھڑنا	4.8 (2.0)	ḥiṛnā	to be touched
008	चलते	5.8 (1.7)	چلتے	6.2 (1.1)	ḥalte	walking
009	जुतवा	2.1 (0.9)	جوتوا	3.5 (2.5)	jutvā	cause to be ploughed
010	गवाना	4.7 (1.5)	گوانا	5.0 (1.9)	gavānā	cause to sing
011	झेलकर	3.8 (1.6)	جھیل کر	5.8 (1.1)	jhelkar	having endured
012	नुचना	3.1 (2.0)	نُچنے	3.3 (1.8)	nuṇā	to be scratched
013	फिरने	4.5 (2.1)	پھرنے	5.8 (1.5)	phirne	to rove
014	छोड़ते	5.9 (1.3)	چھوڑتے	6.0 (1.2)	ḥoṛte	leaving
015	जुड़वाँ	4.8 (1.9)	جڑوا	6.0 (1.4)	jurvā	twin
016	चाटके	3.1 (1.6)	چاٹکے	3.5 (2.3)	ḥāṭke	having licked
017	दिखला	4.2 (2.0)	دیکھلا	5.5 (1.5)	dikhlā	cause to see
018	मुड़ता	3.8 (2.1)	مڑتا	5.1 (1.8)	muṛtā	turning
019	लिखता	6.2 (1.1)	لکھتا	6.1 (1.2)	likhtā	writing
020	रुकता	4.5 (2.0)	رُکتا	5.8 (1.5)	ruktā	stopping
021	मरते	4.6 (1.9)	مرتے	6.5 (0.8)	marte	dying
022	तुड़ना	2.5 (2.2)	ٹوڑنا	3.3 (1.9)	tuṛnā	to be broken
023	गुदवा	2.1 (1.8)	گدوا	2.9 (2.0)	gudvā	cause to be etched
024	खुदना	3.0 (1.7)	کُھدنا	3.8 (2.2)	khudnā	to be dug

Morphological Prime

#	Tgt (H)	Fqcy (H)	Tgt (U)	Fqcy (U)	Phon Trans	Meaning
025	سُلانا	5.2 (2.1)	سُلانا	5.2 (2.2)	sulānā	put to sleep
026	ٹُسوا	2.6 (2.2)	ٹُسوا	2.8 (1.5)	ṭhusvā	cause to be stuffed
027	بھوگتے	3.9 (2.3)	بھوگتے	5.0 (2.2)	bhogte	experiencing
028	لُبھاتا	5.1 (1.4)	لُبھاتا	4.8 (1.7)	lubhātā	coveting
029	دِلانا	5.7 (1.5)	دِلانا	5.8 (1.7)	dilānā	cause to give
030	ڈاکن	2.3 (1.7)	ڈاکن	3.0 (1.8)	ḍākin	bandit (f.)
031	فٹتا	4.5 (2.0)	فٹتا	4.7 (1.7)	phaṭṭā	tearing
032	سِلوا	3.2 (2.2)	سِلوا	5.0 (2.2)	silvā	cause to be sewn
033	دُھلنے	6.2 (1.7)	دُھلنے	5.8 (1.7)	dhulne	to be washed
034	رُلااتا	6.5 (1.0)	رُلااتا	6.2 (1.2)	rulātā	causing to cry
035	فُڑنا	2.5 (1.8)	فُڑنا	4.2 (2.7)	phuṛnā	be burst
036	بِتايا	6.8 (0.4)	بِتايا	6.5 (1.1)	batāyā	told
037	مُولکے	2.3 (2.3)	مُولکے	2.8 (1.8)	molke	having valued
038	پَلکے	4.7 (2.3)	پَلکے	4.2 (2.6)	palke	having reared
039	چُرانا	6.5 (0.5)	چُرانا	5.2 (2.1)	ḥurānā	to steal
040	بِٹھکے	5.1 (2.0)	بِٹھکے	5.5 (1.5)	baiṭhke	having sat
041	بُلوا	5.8 (1.3)	بُلوا	5.3 (2.0)	bulāvā	summons
042	مِلکے	6.4 (1.0)	مِلکے	6.5 (1.1)	milke	having met
043	دُھلنا	5.7 (1.5)	دُھلنا	6.0 (1.6)	ghulnā	to dissolve
044	خُلّتی	5.8 (1.7)	خُلّتی	6.1 (1.3)	khultī	opening
045	پوٹتا	3.4 (2.1)	پوٹتا	4.0 (1.9)	pottā	daubing
046	گِھرتا	5.5 (1.4)	گِھرتا	5.2 (1.9)	ghirtā	being surrounded
047	گھٹکے	3.5 (1.8)	گھٹکے	4.8 (2.3)	ghuṭke	having choked
048	بِکوا	2.6 (1.6)	بِکوا	4.3 (2.1)	bikvā	cause to be sold

Form Prime

#	Tgt (H)	Fqcy (H)	Tgt (U)	Fqcy (U)	Phon Trans	Meaning
001	भीगके	5.9 (1.1)	بھگکے	5.6 (1.7)	bhīgke	having soaked
002	ठुमके	4.8 (1.4)	ٹھمکے	4.2 (2.0)	ṭhumke	flounces
003	लड़वा	2.9 (1.8)	لڑوا	3.8 (2.4)	laṛvā	cause to fight
004	टहला	4.2 (2.0)	ٹہلا	4.8 (2.2)	ṭahlā	cause to stroll
005	खपाया	4.1 (1.9)	کھپایا	5.4 (1.8)	khapāyā	lost
006	लपका	4.5 (1.9)	لپکا	5.1 (1.8)	lapkā	pounced
007	छिलता	3.7 (2.2)	چھلتا	5.1 (1.7)	ḥiltā	peeling
008	चखने	5.0 (1.7)	چکھنے	5.7 (1.4)	ḥakhne	to taste
009	जुगनू	4.5 (1.7)	جگنو	3.9 (2.2)	jugnū	firefly
010	गड़ाया	2.9 (1.5)	گڑایا	4.5 (2.1)	gaṛāyā	caused to be buried
011	झाँकते	5.2 (1.6)	جھانکتے	6.4 (0.8)	jhākte	peeping
012	निचला	5.8 (1.2)	نیچلا	5.7 (1.7)	niḥlā	lower
013	फिसला	5.0 (1.8)	پھسلا	5.8 (1.5)	phislā	slipped
014	छोकरे	3.5 (1.9)	چھوکرے	6.2 (1.8)	ḥokre	lads
015	जुटता	2.7 (1.6)	جٹتا	4.7 (2.4)	juttā	joining
016	चाहते	5.8 (1.3)	چاہتے	6.8 (0.6)	ḥāhte	wishing
017	दफना	3.1 (1.6)	دفنا	4.9 (2.1)	dafnā	to bury
018	मुजरा	1.9 (1.7)	مُجرا	4.7 (2.0)	mujrā	cabaret
019	लिपटा	3.9 (1.8)	لیپٹا	5.3 (1.5)	liptā	wrapped
020	रुसवा	3.6 (1.9)	رُسوا	5.7 (1.6)	rusvā	disgraced
021	मलके	2.2 (1.8)	ملکے	3.4 (2.2)	malke	having rubbed
022	तुतला	2.3 (1.2)	تُتلا	3.3 (1.9)	tutlā	stutter
023	गुथना	2.9 (1.6)	گُٹھنا	3.6 (1.8)	guthnā	to dig
024	खिलना	5.1 (1.8)	کھلنا	5.9 (1.2)	khilnā	to bloom

Form Prime

#	Tgt (H)	Fqcy (H)	Tgt (U)	Fqcy (U)	Phon Trans	Meaning
025	सुनवा	3.3 (2.2)	سُٺوا	3.8 (2.2)	sunvā	cause to listen
026	ठगना	4.0 (2.2)	ٹھگنا	4.8 (2.0)	ṭhagnā	loot
027	भौंकने	4.5 (2.1)	بھونکنے	5.5 (2.0)	bhāũkne	to bark
028	लुटाया	4.5 (1.8)	لُٹایا	6.1 (1.8)	luṭāyā	lavished
029	दीवार	6.8 (0.4)	دیوار	6.8 (0.4)	dīvār	wall
030	डॉटा	5.7 (1.5)	ڈاٹا	5.8 (1.8)	ḍāṭā	rebuked
031	फलना	4.6 (2.3)	फलना	5.2 (2.0)	phalnā	to bear fruit
032	सिंचना	3.5 (2.1)	سینچنا	4.5 (2.4)	sīñnā	to be irrigated
033	धुनकी	2.3 (2.0)	دھنکی	3.2 (2.1)	dhunkī	comb
034	रुपया	6.7 (0.9)	روپيا	6.7 (1.1)	rupyā	unit of currency
035	फुलवा	2.8 (1.3)	فُھلوا	3.1 (2.3)	phulvā	cause to inflate
036	बहला	3.6 (2.1)	بہلا	3.4 (2.0)	bahlā	cheer up
037	मौसमें	5.0 (2.3)	موسے	3.9 (2.6)	mausmē	seasons
038	पहने	6.0 (1.5)	پہنے	6.2 (1.1)	pahne	is worn
039	चुकाए	5.5 (1.6)	چُکائے	4.3 (1.9)	ṭukāe	repaid
040	बेलते	4.4 (2.2)	بیلتے	3.5 (2.3)	belte	rolling (pastry)
041	बुनवा	2.7 (2.1)	بُنوا	3.9 (1.9)	bunvā	cause to knit
042	मिटते	5.8 (1.6)	مٹتے	6.3 (1.2)	mitte	being erased
043	घूमता	6.6 (0.7)	گھومتا	6.6 (0.5)	ghūmtā	wandering
044	खुजवा	2.3 (2.2)	کھجوا	4.2 (2.3)	khujvā	cause to search
045	पोसना	2.3 (1.7)	پوسنا	3.8 (2.0)	posnā	to foster
046	घिसना	5.8 (1.9)	گھسنا	6.3 (1.0)	ghisnā	to scrub
047	घुसते	4.2 (1.7)	گھستے	5.3 (1.2)	ghuste	entering
048	बिछना	3.7 (1.8)	بچھنا	4.8 (2.2)	biñhñā	to be spread

Control Prime

#	Tgt (H)	Fqcy (H)	Tgt (U)	Fqcy (U)	Phon Trans	Meaning
001	दुलहन	6.8 (0.6)	دُلہن	6.5 (0.8)	dulhan	bride
002	मेहमान	6.4 (1.2)	مہمان	6.7 (0.9)	mehmān	guest
003	पुराने	6.3 (1.5)	پرانے	6.2 (1.7)	purāne	old
004	चिकने	6.4 (0.9)	چکنے	5.5 (1.8)	īkne	smooth
005	गरदन	6.1 (1.7)	گردن	6.3 (1.0)	gardan	neck
006	अपना	6.7 (0.6)	اپنا	6.5 (1.1)	apnā	own
007	सोचके	6.2 (0.9)	سوچکے	6.1 (1.7)	soīke	having thought
008	ममता	6.4 (1.1)	ممتا	6.4 (1.0)	mamtā	tenderness
009	हकला	3.5 (2.1)	ہکلا	4.5 (2.2)	haklā	stammer
010	मकड़ी	3.8 (2.0)	مکڑی	5.5 (1.9)	makḍī	spider
011	सचमुच	5.2 (1.9)	سچ مچ	6.3 (0.9)	saīmuī	truly
012	बलखाई	2.8 (2.0)	بلخائی	4.5 (1.9)	balkhāī	swayed
013	झगड़ा	5.6 (1.3)	جھڑا	6.2 (1.1)	jhagdā	quarrel
014	बुलबुल	4.7 (1.6)	بُلبل	6.6 (0.9)	bilkul	nightingale
015	हालचाल	6.2 (1.0)	حال چال	6.9 (0.3)	hālīāl	condition
016	गिनती	6.1 (1.8)	گنتی	6.5 (1.2)	gintī	count
017	परवाह	4.7 (1.8)	پر واه	5.5 (1.9)	parvāh	care
018	पुतली	2.7 (2.1)	پُتلی	4.8 (1.6)	putlī	puppet
019	फुरसत	4.9 (2.3)	فرست	6.1 (1.4)	fursat	leisure
020	धड़कन	5.8 (1.8)	دھڑکن	5.6 (1.3)	dhaṛkan	throb
021	पोटली	2.2 (2.0)	پوٹلی	4.2 (1.9)	poṭlī	knapsack
022	लुटकर	3.6 (2.2)	لُٹکر	5.3 (1.7)	luṭkar	having been plundered
023	चीरके	2.4 (1.3)	چیرکے	5.0 (1.7)	īrke	having ripped
024	रोशनी	6.5 (1.4)	روشنی	6.4 (0.7)	rošnī	light

Control Prime

#	Tgt (H)	Fqcy (H)	Tgt (U)	Fqcy (U)	Phon Trans	Meaning
025	बसना	5.3 (1.4)	بسا	5.5 (1.6)	basnā	to settle
026	खोपड़ी	5.2 (1.3)	کھوپڑی	5.4 (1.3)	khopṛī	skull
027	शलवार	4.6 (2.1)	شلوار	4.8 (2.4)	šalvār	tunic
028	बजवा	2.5 (2.0)	بجوا	3.1 (2.0)	bajvā	cause to play
029	मचाए	4.3 (1.5)	مچائے	5.8 (1.8)	maṭṭāe	created
030	मौलवी	5.3 (1.5)	مولوی	6.0 (1.5)	maulvī	religious teacher
031	जमके	4.2 (2.4)	جمنکے	5.4 (1.8)	jamke	having solidified
032	चमड़ा	5.3 (2.1)	چمڑا	5.3 (1.8)	ṭamṛā	hide
033	नहला	3.8 (1.9)	نہلا	4.9 (2.2)	nahlā	give a bath
034	टुकड़ा	5.6 (1.5)	ٹکڑا	5.2 (2.2)	ṭukṛā	piece
035	नटखट	5.3 (1.7)	نٹکھٹ	4.5 (2.1)	naṭkhaṭ	naughty
036	नौकरी	6.7 (0.9)	نوکری	6.8 (0.6)	naukrī	employment
037	राहगीर	5.8 (1.7)	راہگیر	5.5 (1.9)	rāhgīr	traveler
038	चबाया	5.4 (0.9)	چبايا	4.9 (2.0)	ṭabāyā	chewed
039	कपड़ा	6.9 (0.3)	کپڑا	6.9 (0.3)	kapṛā	cloth
040	कचरा	5.6 (1.7)	کچرا	4.8 (2.2)	kaṭṛā	rubbish
041	तड़का	4.3 (2.2)	تڑکا	5.0 (2.0)	taṛkā	seasoning
042	गड़बड़	5.2 (2.1)	گڑبڑ	6.2 (1.6)	gaṛbaṛ	muddle
043	मुझसे	6.5 (1.2)	مجھ سے	6.5 (1.0)	mujhse	than me
044	दरजन	5.3 (1.7)	درجن	4.8 (2.0)	darjan	dozen
045	कौनसी	6.5 (1.2)	کون سی	5.9 (1.4)	kaunsī	which
046	हलवा	4.5 (1.6)	حلوه	6.0 (1.2)	ḥalvā	sweetmeat
047	तुमने	6.6 (0.9)	تم نے	6.8 (0.6)	tumne	you (agentive)
048	सगाई	4.9 (1.6)	سگائی	5.9 (1.8)	sagāi	engagement

APPENDIX D: ANOVA TABLES

Table D-1

Exp. 1: ANOVA showing the effects of Script, Prime Type and SOA on participant and item mean proportion accuracy and naming latency (Reaction Time) in Hindi vs. Urdu (n = 92)

Accuracy	Participant ANOVA					Item ANOVA			
	df ₁	df ₂	MSE	F ₁		df ₁	df ₂	MSE	F ₂
Script	1	89	0.004	39.09 [†]		1	77	0.011	35.00 [‡]
Script × SOA	2	89	0.001	0.20		2	154	0.006	0.58
Prime Type	2	178	0.002	0.29		2	154	0.006	0.67
Prime Type × SOA	4	178	0.002	0.46		4	308	0.006	0.36
Script × Prime Type	2	178	0.002	0.42		2	154	0.006	0.61
Script × Prime Type × SOA	1	178	0.002	0.43		4	308	0.006	1.32
SOA	2	89	0.004	0.71		2	154	0.007	2.06
Reaction Time (RT)									
Script	1	89	14368	107.30 [‡]		1	77	20789	194.39 [‡]
Script × SOA	2	89	14368	0.51		2	154	7137	3.72*
Prime Type	2	178	838	54.55 [‡]		2	154	5177	22.63 [‡]
Prime Type × SOA	4	178	838	0.41		4	308	4991	0.26
Script × Prime Type	2	178	1084	0.09		2	154	3470	0.02
Script × Prime Type × SOA	1	178	1084	2.55*		4	308	5467	1.59
SOA	2	89	48324	1.88		2	154	2955	87.63 [‡]

[†]Significance levels indicated by * ($p < .05$), [†] ($p < .01$) and [‡] ($p < .001$).

Table D-2

Exp. 2: ANOVA showing the effects of Script, Prime Type and SOA on participant and item mean proportion accuracy and naming latency (Reaction Time) in Hindi vs. Urdu (n = 32)

	Participant ANOVA					Item ANOVA			
Accuracy		df ₁	df ₂	MSE	F ₁	df ₁	df ₂	MSE	F ₂
	Script	1	30	0.004	5.57* ¹	1	77	0.014	16.82‡
	Script × SOA	1	30	0.004	1.55	1	77	0.015	0.00
	Prime Type	2	60	0.003	1.67	1	77	0.016	1.45
	Prime Type × SOA	2	60	0.003	0.19	2	154	0.024	0.06
	Script × Prime Type	2	60	0.003	0.09	2	154	0.011	0.03
	Script × Prime Type × SOA	2	60	0.003	0.54	2	154	0.019	0.08
	SOA	1	30	0.007	0.00	2	154	0.019	0.11
Reaction Time									
	Script	1	30	21975	31.35‡	1	77	20789	271.19‡
	Script × SOA	1	30	21975	0.57	1	77	7137	7.48†
	Prime Type	2	60	893	18.85‡	1	77	5177	16.79‡
	Prime Type × SOA	2	60	893	1.51	2	154	4991	1.81
	Script × Prime Type	2	60	683	0.83	2	154	3470	0.98
	Script × Prime Type × SOA	2	60	683	1.74	2	154	5467	0.62
	SOA	1	30	41747	1.83	2	154	2955	56.12‡

¹Significance levels indicated by * ($p < .05$), † ($p < .01$) and ‡ ($p < .001$).

Table D-3

Exp. 3: ANOVA showing the effects of Script, Prime Type, SOA and Masking on participant and item mean proportion accuracy in Hindi vs. Urdu (n = 81)

	Participant ANOVA				Item ANOVA				
Accuracy		df ₁	df ₂	MSE	F ₁	df ₁	df ₂	MSE	F ₂
	Script	1	77	0.008	21.80 ^{‡1}	1	47	0.055	10.75 [†]
	Script × SOA	1	77	0.008	0.01	1	47	0.023	0.01
	Script × Masking	1	77	0.008	2.10	1	47	0.026	0.99
	Script × SOA × Masking	1	77	0.008	7.38 [†]	1	47	0.028	5.38*
	Prime Type	2	154	0.012	0.83	2	94	0.033	0.59
	Prime Type × SOA	2	154	0.011	0.04	2	94	0.026	0.06
	Prime Type × Masking	2	154	0.011	0.01	2	94	0.024	0.20
	Prime Type × SOA × Masking	2	154	0.008	0.69	2	94	0.019	1.36
	Script × Prime Type	2	154	0.008	3.92*	2	94	0.024	2.77 [▪]
	Script × Prime Type × SOA	2	154	0.018	1.55	2	94	0.021	1.51
	Script × Prime Type × Masking	2	154	0.018	1.22	2	94	0.020	1.42
	Scr. × Pr. Type × SOA × Masking	2	154	0.018	1.45	2	94	0.022	1.92
	SOA	1	77	0.018	0.93	1	47	0.019	2.91 [▪]
	Masking	1	77	0.018	4.38*	1	47	0.032	5.64*
	SOA × Masking	1	77	0.018	0.45	1	47	0.028	0.44

¹Significance levels indicated by [▪] (.10 ≤ *p* ≤ .05), * (*p* < .05), [†] (*p* < .01) and [‡] (*p* < .001).

Table D-4

Exp. 3: ANOVA showing the effects of Script, Prime Type, SOA and Masking on participant and item mean naming latency (Reaction Time) in Hindi vs. Urdu (n = 81)

Reaction Time	Participant ANOVA				Item ANOVA			
	df ₁	df ₂	MSE	F ₁	df ₁	df ₂	MSE	F ₂
Script	1	77	38383	65.08 [†]	1	47	63580	85.89 [‡]
Script × SOA	1	77	38383	0.13	1	47	28215	0.59
Script × Masking	1	77	38383	5.63*	1	47	14813	31.17 [‡]
Script × SOA × Masking	1	77	38383	1.10	1	47	21136	5.43*
Prime Type	2	154	8917	6.45 [†]	2	94	24087	6.30 [†]
Prime Type × SOA	2	154	8917	0.13	2	94	16482	0.42
Prime Type × Masking	2	154	8917	0.46	2	94	32949	0.44
Prime Type × SOA × Masking	2	154	8917	0.50	2	94	15695	0.13
Script × Prime Type	2	154	6014	3.03*	2	94	35382	0.95
Script × Prime Type × SOA	2	154	6014	1.93	2	94	28745	0.30
Script × Prime Type × Masking	2	154	6014	0.31	2	94	15987	0.77
Scr. × Pr. Type × SOA × Masking	2	154	6014	0.85	2	94	20633	0.50
SOA	1	77	133984	7.03 [†]	1	47	14678	154.54 [‡]
Masking	1	77	133984	11.39 [‡]	1	47	20660	153.30 [‡]
SOA × Masking	1	77	133984	0.01	1	47	12840	0.59

¹Significance levels indicated by • (.10 ≤ *p* ≤ .05), * (*p* < .05), † (*p* < .01) and ‡ (*p* < 001).

VITA

Name	Chaitra Rao
Address	3991, JCO Quarters, Jalpuri, Mahadevapura Main Road, Mysore 570 019, India
Email address	chaitlee@gmail.com
Education	Bac., Psychology, Sociology, English Literature, University of Mysore, 1997
	M.A., Psychology, University of Mysore, 1999
	PhD, Psychology, University of Mysore, 2006
	PhD, Psychology, Texas A&M University, 2010