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# Psycholinguistics

Abstract: Languages are fascinating, complex systems that vary in terms of the linguistic devices and mechanisms that are available to encode our thoughts, ideas, perceptions, and experiences of the world around us. Moreover, the scripts used to encode these languages offer fascinating opportunities to contrast the effects of script-specific features on cognition. The aim of the current chapter is to examine some of the contrasting features of languages and scripts and to what extent they differentially affect cognition in observable and measurable ways. Advances in technology offer novel approaches to addressing these questions. Specific reference has been made to the characteristics of the Thai language and its script. The main characteristics of the Thai language and its script are reviewed prior to examining some research on the relationship between language and cognition. Initially, the focus is on expression of motion events in relation to (1) satellite-framed (e.g., English), verb-framed (e.g., French) and equipollently framed (e.g., Thai and Chinese) languages and in reference to (2) the presence or absence of durative aspectual marking. Subsequently, a focus on script-specific features is reviewed in relation to (3) linear-nonlinear spatial configuration of scripts and (4) the presence or absence of mirror letter pairs (e.g., *b* vs. *d* or *p* vs. *q*). We also make some suggestions for future research utilizing some of the distinctive features of the languages and writing systems of the Asian region.

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# Effects of spoken and written language on cognition

## Evidence from Thai and other Asian languages

**Heather Winskel**

## Introduction

Languages are fascinating, complex systems that vary in terms of the linguistic devices and mechanisms that are available to encode our thoughts, ideas, perceptions, and experiences of the world around us. Each language has a unique system of lexical and grammatical devices that carve up or partition reality in somewhat different ways. Some languages have rich rhetorical choices for representing particular sensory experiences; for example, Lao and Umpila (an Australian Aboriginal language) have codability (more consistently nameable categories) for certain odors but have fewer terms for colors than, for example, English or Cantonese (Majid et al. 2018). An intriguing question arising from this debate is to what extent this linguistic variation affects our cognition. According to the Whorfian or linguistic relativity hypothesis, speakers of different languages have different ways of conceptualizing or perceiving the world due to this linguistic variation (Whorf 1956). A weaker version adopts the view that distinctions in a language that are grammaticized, obligatory, or habitually used have a channeling effect on attention toward particular functions of these forms during the actual on-line processing of language (Berman and Slobin 1994; Slobin 1996; Slobin 2003; Strömqvist and Verhoeven 2004). This has been termed *thinking for speaking*. An alternative, more pervasive off-line perspective is that there are longer term, non-linguistic cognitive consequences of this linguistic diversity.

In the Asian region, there is a rich and diverse array of languages spoken, which vary considerably in how they encode and semantically partition the world. Contemporary researchers investigating linguistic relativity adopt a more nuanced approach and consider the various factors that contribute to any observable or measurable effects on cognition in different language domains (Athanasopoulos and Casaponsa 2020). Advances in technology have also provided a more systematic and scientific way of investigating these language-specific effects on cognition. Recent research is beginning to investigate whether neurophysiological mechanisms reflect these linguistic differences in languages (e.g., Athanasopoulos et al. 2016; Athanasopoulos and Casaponsa 2020; Lupyan et al. 2020; Maier and Abdel Ramen 2018; Meyer et al. 2019; Papafragou and Grigoroglou 2019). Notably, there are also a remarkable number of writing systems with very different characteristics or features in the Asian region that form useful comparisons with the extensively studied Roman script. The rich scripts and writing systems of this region offer fascinating opportunities to contrast the effects of script-specific features on cognition. Recently, Pae (2020) has referred to these script-on-cognition effects as the 'script relativity hypothesis'.

The aim of this chapter is to examine some of the contrasting features of languages and scripts that affect attention allocation and, in turn, cognition. The allocation of attention plays a key role in these linguistic and script-specific contrasting effects. A particular reference will be made to the characteristics of the Thai language and its script. We will first review the main characteristics of the Thai language and its script prior to examining some research on the relationship between language and cognition. Initially, the focus will be on expression of motion events in relation to (1) satellite-framed (e.g., English), verb-framed (e.g., French) and equipollently framed (e.g., Thai and Chinese) languages and in reference to (2) the presence or absence of durative aspectual marking. Subsequently, a focus on script-specific features will be reviewed in relation to (3) linear-nonlinear spatial configuration of scripts and (4) the presence or absence of mirror letter pairs (e.g., *b* vs. *d* or *p* vs. *q*). The key question posed here is to what extent these contrasts or variations in language and script characteristics result in measurable or observable cognitive consequences. We will also make

some suggestions for future research utilizing some of the distinctive features of the languages and writing systems of the Asian region.

# Thai language and its script

Thai is a tonal language, which is a characteristic it shares with other regional neighbors (e.g., Chinese, Burmese, Lao, and Vietnamese) (Winskel 2014; Winskel and Ratitamkul 2019). Lexical tone serves an essential function in distinguishing meanings of words with identical phonological structure. Thai is predominantly a monosyllabic language but also has polysyllabic words, which have been borrowed mainly from Khmer, Pali, or Sanskrit. Thai is an analytic (or isolating) language: that is, the word forms do not change; it is similar in this respect to many other languages in the Southeast Asian region. Thus, Thai does not have complicated inflectional morphology and instead has affixation and compounding. In addition, Thai is a serial-verb language, in which strings of verbs are juxtaposed around a head verb to form complex verb phrases. Notably, Thai has a rich aspectual system with aspect, not tense, as the primary inflectional category for verbs (Matisoff 1983). Thai verbs have no inflection for time or number. Instead, context, added time expressions, or preverbs generally specify the tense. Subject-verb-object is the favored word order. Thai also has a numerical noun classifier system. Thai shares many of these characteristics with regional neighbors such as Chinese.

The Thai alphabet has 44 basic consonants plus 4 archaic consonants (≈, ≈Â «, «Â) that correspond to 21 consonant sounds. It is read from left to right. The script has a nonlinear or nonsequential configuration as vowels can occur above or below the main text line or on either side of the consonant as full letters or diacritics, which commonly combine across the syllable to produce a single vowel or diphthong (e.g., ‡Õ®/**e:**hŋ**a:**/‘cold’ is spoken as /ŋaw/). The phonological representation of vowels may not adhere to the orthographic sequence (e.g., ·¿∫ <ɛ:fn> is spoken as /fɛ:n/ ‘boy/girlfriend’ or an English example: ‘odg’ would be read as /dog/) (see Winskel 2009). These are termed nonaligned vowels. In addition, vowels are not always explicitly written in Thai. Instead, inherent vowels (a consonant without a vowel

grapheme) can occur; an *a* is usually found in words of Sanskrit, Pali, or Khmer origin, whereas an *o* is found in native Thai words (e.g., ตลาด/t[a]la:t/ ‘market’ or ลม/l[o]m/ ‘wind’; the inherent vowels are in brackets). A notable feature is that lexical tone is visually or orthographically represented in Thai script, which also occurs in Burmese and Vietnamese. Thai does not have interword spaces, similar to Chinese, Japanese, Lao, Khmer, Tibetan, and Burmese. Due to these combined characteristics, Thai script is relatively dense or crowded and exerts distinct challenges to the child learning to read and spell Thai (Winskel and Iemwanthong 2010). An additional feature that makes interesting comparisons with Roman script is that Thai script does not have mirror letter pairs as occur in Roman script (i.e., *b* vs. *d* or *p* vs. *q*). Thai language and its script have distinctive features that offer fruitful opportunities to investigate language and script-specific effects on attentional mechanisms and cognitive processes (refer to Winskel and Ratitamkul 2019 for more detail). It forms useful comparisons with the much-studied European languages and Roman script.

# Language-specific effects on cognition

From an early age, language begins to shape our cognitive processes. Over the first year of life, infants gradually change from being universal listeners to tuning into the language-specific speech categories of their language (e.g., Werker and Tees 1984). Subsequently, children learn how their language maps onto different aspects of their experienced world. In fact, children learn how their language partitions the semantic domain from a very early stage of development. This has been demonstrated by Bowerman and colleagues, who tracked the development of locative placement expressions in Korean and English children (Bowerman and Choi 2003; Choi and Bowerman 1991; Choi et al. 1999). In English, there is a major semantic division between containment and contact with an external surface: that is, whether an object is in or on another or whether an object is taken off or out in relation to another, whereas in Korean, there is a major semantic division or distinction between actions that result in tight fit and actions that result in the other types of contact. Bowerman and colleagues found that both English and Korean children are sensitive to and start to produce

language-specific spatial categories or divisions from a very early age. Hence, it can be seen how language-specific semantic categories of the child's language gradually shape semantic and conceptual development. Children acquiring a language tune into the obligatory or habitually used categories of their language and represent events in the style of their particular language from an early age and in a typical way that their language encodes experience (Bowerman and Choi 2003; Choi and Bowerman 1991; Choi et al. 1999). Thus, the child learns 'language-specific patterns of thinking for speaking' from early in language development (Slobin 1996: 77).

As well as distinctions that are grammaticized, obligatory, or habitually used in a language, codability is also considered to be a key factor in the ability to access and process a linguistic term (Athanasopoulos and Casaponsa 2020). If there is a single label or term to refer to a particular concept, then it is considered to be more codable. Basically, the fewer words it takes to refer to a concept, the more codable it is considered. As an example, some languages distinguish and have separate labels for 'light blue' and 'dark blue' (e.g., Greek, Thai, Japanese, Chinese), whereas others do not (e.g., English, French). This specific labelling of color categories on the color spectrum continuum has been found to have perceptual consequences, as colors can be recognized faster in discrimination tasks if they have specific linguistic terms or labels assigned to them (Athanasopoulos and Casaponsa 2020; Maier and Abdul Ramen 2018). A consistent finding from this research is that labels or terms used in a language result in us perceiving in a more categorical manner (Lupyan et al. 2020).

# Expression of motion events

## Satellite-, verb-, and equipollently framed languages

From a theoretical perspective, Levelt's (1989) speech production model proposes that there are language-specific demands on the formulation of messages that shape the preparation of encodable messages even before the activation of specific lexical items (Meyer et al. 2019;

Papafragou and Grigoroglou 2019). Thus, according to this model, there are early detectable differences in attention allocation in speakers of typologically contrasting languages as they prepare to describe an event or action. There is some empirical research on expression of manner and path in motion events that supports this model. This research has primarily focused on the distinction between satellite- and verb-framed languages. In satellite-framed languages (e.g., English, other Germanic and Slavic languages), manner is encoded in the verb (e.g., *run*) and path is expressed using a variety of other satellite devices (e.g., *in* or *out*). In contrast, in verb-framed languages (e.g., French, other Romance and Semitic languages), path is typically encoded in the verb (e.g., *entre, sortir*), and manner is expressed using additional lexical devices (e.g., *entre en courant* 'enter while running'). When describing events, speakers of verb-framed languages tend not to express manner of motion as frequently as speakers of satellite-framed languages (Slobin 2003, 2004). The more indirect means used to express manner in satellite-framed languages are considered to be less codable or accessible as they are expressed in a phrase rather than a single word, which requires an additional processing load. Thus, the perspective taken when describing actions and events can be quite different in emphasis in these typologically contrasting languages.

Thai, along with Mandarin Chinese, belongs to yet another typological group: namely equipollently framed languages. In equipollently framed languages (e.g., Chen and Guo 2009; Shan 2018; Slobin 2004; Zlatev and Yangklang 2004), both manner and path are expressed concurrently using equivalently weighted verbs. Here is an example from *The Frog Story* (Mayer 1969) in Thai (Winskel and Luksaneeyanawin 2009; Zlatev and Yangklang 2004) and in Mandarin Chinese (Slobin 2006).

*nók hû:k bin ʔcʉ̀:k1 ma:*

owl fly leave come

manner path deictic-path

'The owl flies out.'

*fei1 chu1 lai2 yi1 zhi1 mao1tou2ying1*

fly exit come one only owl

manner path deictic-path

'The owl flies out.'

The equipollently framed languages offer fruitful opportunities for research on attention allocation. It would be informative to compare how Thai and Chinese children and adults describe motion events when viewing short animations.

# Durative/non-durative aspectual contrasts

The presence or absence of grammatical aspect in a language has also been shown to affect the extent to which speakers pay attention to and describe actions and motion events. Research has found that languages with obligatory grammatical marking of durative aspect (e.g., Spanish, Turkish, and English) tend to express the overlapping temporal relations depicted in *The Frog Story* picture book (Mayer 1969) using the aspectual forms available (e.g., the morpheme *-ing* in English), whereas German and Hebrew speakers who do not have this obligatory aspectual marking tend not to express the temporal distinctions depicted, even though there are alternative, less direct lexical means of expression (Berman and Slobin 1994). Instead, there is a tendency for German and Hebrew speakers to describe the events depicted in a sequential linear manner without expressing the duration of the events or actions. Speakers of non-aspect languages (that do not encode aspect systematically on the verb) have also been shown to have a linguistic bias toward action goals and motion event endpoints, whereas aspectual language speakers tend not to mention endpoints of motion events unless they are specifically focused on (Bylund et al. 2013; Schmiedtová et al. 2011). In sum, a higher degree of attention is allocated to event endpoints by non-aspect language users such as German or Hebrew speakers than by speakers of English, for example. Thus, this typological distinction influences the particular rhetorical choices and perspectives taken when describing motion events and actions (Strömqvist and Verhoeven 2004).

Languages such as Thai and Chinese have rich aspectual systems that consist of separate morphemes (Kanchanawan 1978; Koenig and Muansuwan 2005; Schmidt 1992; Thepkanjana 1986). Thai has the imperfective aspectual morphemes *kamlaŋ* and *jù:* that are optional and not obligatory in usage (Winskel 2007). In addition, Thai has verb final deictic path verbs that form a closed class set consisting of only two verbs (*paj* 'go' or *ma:* 'come') that are frequently used when expressing motion of events. Consequently, Zlatev and Yangklang (2004) have suggested that deixis is a grammaticalized category in Thai. These characteristics make interesting comparisons with the previously studied European language aspectual systems.

In order to investigate whether the relative degree of obligatoriness of grammatical aspectual marking has an influence on how temporal events and actions are expressed, Winskel and Luksaneeyanawin (2009 compared the linguistic expressions produced by Thai and English children aged four years, five years, six years, and seven years and adults when describing two overlapping events portrayed in short animations (e.g., a monkey drawing and a child painting). The speech produced by the participants was analyzed in terms of explicit expressions of the ongoingness of the two events and the entrance and exit of protagonists depicted in the animations (e.g., the monkey entering or the child leaving the room). English speakers explicitly expressed the ongoingness of the events more than Thai speakers, whereas Thai speakers expressed the entrance and exit of protagonists depicted in the animations significantly more. These results suggest that the relative obligatoriness of the grammatical categories influence how Thai and English speakers verbally express temporal events or actions. It would be interesting to see if eye tacking and neurophysiological evidence corroborates the language use patterns.

# Eye tracking and neurophysiological evidence

More recent research has used eye-tracking technology as that gives detailed moment-to-moment information about attention allocation while speakers are preparing to speak and while they are actually speaking. Papafragou et al. (2008) examined eye movements of

English and Greek speakers while they viewed short animations showing either bounded (e.g., man skiing to a snowman) or unbounded events (e.g., man skiing). As stated previously, English is classified as a satellite-framed language whereas Greek has been classified as a verb-framed language (Papafragou et al. 2002). However, a more recent perspective is that languages fall on a continuum in relation to manner and path salience, and Greek is in between as it has both satellite- and verb-framed characteristics (Soroli and Verkerk 2017). English speakers, when describing bounded motion events, typically select verbs that convey information about manner (e.g., run), whereas Greek speakers tend to use verbs that express path (e.g., enter). For the bounded events, the Greek speakers first looked at the path endpoint and then switched to manner of motion, whereas the English speakers did the opposite. However, no differences were found for the unbounded events. These results lend support to Levelt's speech production model and the thinking-for-speaking hypothesis as differences between English and Greek speakers emerged while speakers were preparing to speak (Papafragou et al. 2008; Papafragou and Grigoroglou 2019; Papafragou et al. 2002). Even during the first second of the animation, there was a significant difference in which region was fixated by speakers from the two language groups.

Recent neurophysiological evidence, using event-related potentials (ERPs), supports the behavioral findings that conceptual distinctions in languages impact attention and neuro-cognitive processing. Flecken et al. (2015) investigated whether grammatical differences in English and German affect visual attention allocation to elements of motion events in a non-verbal context using electrophysiological measures. Native English and German speakers were asked to perform a matching task while ERPs were recorded. The English and German participants were asked to note the trajectory and the endpoint in a short animation (e.g., a dot moving along a straight trajectory toward a square) and then match those features to the subsequently presented target picture. When recording ERPs, the researchers focused on P3 amplitudes (neural activity measured in the parietal region) as it reflects attentional processing, stimulus evaluation, and target detection (Polich 2007). They found that German speakers showed greater P3 amplitudes for the endpoint match than the trajectory match conditions, whereas English participants did not show differences for those two conditions.

This was interpreted as indicating support for the behavioral observations that attention is allocated to event endpoints in non-durative aspect languages such as German, in contrast to durative aspect languages such as English. Future studies could utilize eye-tracking and neurophysiological techniques to investigate attention allocation while viewing actions and events presented in short videos or animations in equipollently framed languages with rich aspectual marking, such as Thai and Chinese.

# Script-specific effects on cognition

There are numerous writing systems around the world that have distinct and contrasting characteristics or features. The majority of research has focused on Roman script; consequently, there is a critical absence of research on other scripts. When learning to read, learners need to attend to the distinctive visual features of the script that interface with their respective language. Thus, similar to language-specific features, attentional resources need to be differentially allocated dependent on the specific characteristics or features of the orthography and the role that they play when forming a coherent mental representation of the printed words on the page.

Neurophysiological research has demonstrated that becoming literate has profound effects on the brain and associated neural and cortical networks (e.g., Dehaene et al. 2010; Dehaene et al. 2015; Dehaene-Lambertz et al. 2018; Huettig et al. 2018). The brain is restructured and rewired when learning to read, which reflects the different characteristics and cognitive demands of that particular writing system. This neurophysiological evidence provides support for the view that scripts can have varying effects on cognition, similar in this respect to language-specific effects.

In relation to script-on-cognition effects, habitually reading and writing in a particular direction – for example left to right (e.g., English), right to left (e.g., Arabic) or up-down (e.g., Chinese) – has been shown to have an effect on off-line non-linguistic cognitive processing. For example, robust effects have been found from reading direction on numerical cognition tasks (e.g., Azhar et al. 2020; Göbel 2015; Singh et al. 2000), spatial and scanning

biases in drawing (Faghihi et al. 2018, 2019; Padakannaya et al. 2002; Tosun and Vaid 2014; Vaid 1995), and aesthetic preference biases (Friedrich and Elias 2016). Other script-specific contrasts are unlikely to have such an impact as the overt behavior of reading or writing direction.

# Linear/nonlinear spatial configuration of scripts

Thai and other scripts such as Burmese, Devanagari, Kannada, and Korean Hangul have a nonlinear configuration, which makes interesting and informative contrasts to linear Roman script, where letters are written in a sequential order from left to right. In nonlinear scripts, there is more densely packed and perceptually crowded information contained in the text as additional letters or diacritics may occur above or below the main text line encoding vowel, consonant, or tone information. In addition, vowels may not adhere to the orthographic sequence. This is exacerbated when interword spaces are lacking, as occurs in scripts such as Thai. The question debated here is whether this variation in script-specific features results in measurable or observable cognitive outcomes.

In Roman script, the initial letter plays a critical role in lexical access and processing. Numerous studies have shown that letter position coding is flexible in middle letter positions, but not in the initial letter position, as illustrated by *jugde*, which closely resembles *judge* while *ujdge* does not. The widely held view is that initial letter position has a special role for word recognition in comparison to internal letters in Roman script (e.g., Chambers 1979; Estes et al. 1976; Gómez et al. 2008; Jordan et al. 2003; Perea 1998; Rayner and Kaiser 1975; White et al. 2008). In line with this view, research on Roman script has not detected a masked transposed-letter priming effect when the initial letter is involved. In other words, a target word (e.g., *JUDGE*) is responded to more rapidly when it has been briefly preceded by a middle-letter transposed letter prime (e.g., *jugde*) in comparison to an orthographic control prime (e.g., the replacement-letter prime *jupte*), but this contrast does not occur when it is preceded by an initial-letter transposed prime (e.g., *ujdge*) (e.g., Perea and Lupker 2007).

We investigated if this initial letter advantage in word recognition also occurs in nonlinear Thai. As Thai has nonaligned vowels, in which the orthographic and phonological order of vowels does not necessarily correspond, we suspected that letter position coding could be more flexible than in English. After all, Thai readers need to be able to encode the letter positions of words with or without these nonaligned vowels. In order to examine this, we conducted a lexical decision masked priming experiment (Forster and Davis 1984). In contrast to research conducted on Roman script, we found a significant masked transposed-letter priming effect when the initial letter was transposed even in short words (e.g., “ª∏ª ‘∏ was recognized faster than ø“∏ª ‘∏[[transposed-letter condition versus replacement-letter condition]) (Perea et al. 2012). This suggests that the role played by the initial letter in Thai is not as critical as in Roman script.

In a follow-up study (Winskel et al. 2012), we examined if initial letters have a privileged position in comparison to internal letters in Thai during normal silent reading. The eye movements of participants were monitored while they read sentences with target words with internal (e.g., *problem*) and external (e.g., *rpoblem*) transposed letters. Results revealed that there was no apparent difference in degree of disruption caused when reading internal and initial transposed-letter nonwords. This is in marked contrast to results found in Roman script, where greater disruption was caused by initial than internal transpositions (White et al. 2008). Thus, these findings on Thai give further support to the view that letter position encoding is relatively flexible, even for the initial letter position. This is line with the characteristics of Thai: that is, the nonaligned vowels.

We also used a two-alternative forced choice (2AFC) procedure to investigate processing of letter strings in Thai (Winskel et al. 2014). In that procedure, participants are asked to identify which of two characters have previously been briefly presented to them in a five-character array of letters (e.g., ¢, µ, ∫, ∆ Àor B, D, F, G, K). Identification accuracy can be measured at all positions in the string of five letters, digits, or symbols. For Roman script readers, typically, a W-shaped function for Roman letters and a Λ-shaped function for symbols (e.g., *, #, +) is found (Tydgat and Grainger 2009). In other words, there is higher accuracy, notably, for recall of the letter in the initial position but also middle and final

positions in the array of five letters. In contrast, in Thai, we found a common advantage for initial, second, and third letter positions and that Thai readers responded with a similar response pattern to Roman letters, Thai letters, and symbols.

When we conducted a similar study with readers of Sinhala, another nonlinear Brahmi-derived script (Jayawardena and Winskel 2016), we also found a common advantage for initial, second, and third letter positions as occurs in Thai. This appears to reflect the shared nonaligned vowel characteristic of Sinhala and Thai orthographies and the more flexible adaptation necessary for processing scripts with these types of vowels. Both scripts have vowels for which orthographic order does not necessarily correspond to phonological order. Thai has five of these types of vowels, and Sinhala has one commonly occurring vowel (the Kombuwa ෙ ා). This means that the consonant that the vowel modifies can be written in second or third position, respectively, and yet when the word is read, the phonological form of the consonant occurs first. However, we also found discrepancies in the serial string identification patterns for native Sinhala and Thai readers. In contrast to the Thai readers, Sinhala readers displayed distinct patterns when responding to the letters and symbols, similar in this respect to Roman script readers. This disparity in results could be due to script-specific differences as Thai does not have interword spaces whereas Sinhala does. This means that Thai readers have the additional task of segmenting words using other cues besides salient interword spaces, possibly resulting in more finely tuned perceptual discrimination abilities.

In sum, research indicates that in Thai and Sinhala, there is a very flexible process of letter position coding and that the initial letter position is not as critical as in Roman script. There was a heightened attentional response to initial letter positions (rather than just initial letter position as occurred in Roman script) in Thai and Sinhala readers (Jayawardena and Winskel 2016; Winskel et al. 2014). In both Thai and Sinhala scripts, the critical initial phonological letter of a word, which is crucial for lexical access, may occur in first, second, or even third position due to their shared nonaligned vowel characteristic, in which orthographic order does not necessarily correspond to phonological order. These results

indicate that this script-specific feature affects attention allocation when converting orthographic code to phonological code.

# Mirror letters

When children are learning to read, they commonly make mirror reversal errors involving single letters or even entire words. These reversals can be particularly problematic for struggling readers or children with dyslexia (e.g., Badian 2005; Fernandes and Leite 2017). Mirror letter pairs (e.g., *b* vs. *d* and *p* vs. *q*) can be particularly challenging to young readers learning to read a language that uses Roman script, for example. However, many other scripts, such as Thai and Tamil, do not have mirror letter pairs. Mirror letters are of particular interest when reading as the visual system is originally designed to recognize objects, faces, or predators as being the same image regardless of their spatial orientation. This basic recognition ability is referred to as mirror-image generalization or mirror invariance. But here is where the difficulty arises when learning to read a script with mirror letters (e.g., *b* vs. *d* and *p* vs. *q*): the process of learning to read inherits the functional properties of the original visual system and its cortical network: namely, mirror invariance. As reading is a relatively recent cultural invention, there is no designated region of the brain associated with that function. Instead, it has been found to piggyback onto pre-existing regions of the visual cortex that are typically used for recognizing objects, faces, or predators (e.g., Dehaene 2005; Dehaene and Cohen 2007; Dehaene et al. 2015; Dehaene et al. 2005; Dehaene et al. 2010; Dehaene-Lambertz et al. 2018). Thus, in order to read Roman script and be able to distinguish between mirror letters and words containing those mirror letters (e.g., *bad* and *dad*), mirror invariance needs to be suppressed or broken.

As stated previously, Thai and many other scripts, including Tamil, do not have mirror letters, in contrast to Roman script. Previous research on Tamil indicates that readers remained poor at mirror discrimination of geometric figures and identified them as if they were the same object (Danziger and Pederson 1998; Pederson 2003). Tamil readers and illiterates tended to respond similarly to both identical and mirror images. In a study on Thai,

Winskel and Perea (2018) used a same-different masked priming task with mirror primes composed of Thai and English words with mirror letters (the two middle letters were rotated on the vertical axis). Results revealed that the mirror prime had a similar facilitative effect as the identical prime in Thai readers, whereas this was not apparent in the English readers. Thus, the Thais were more likely to perceive mirror letters and identical letters similarly than English readers. These results on Thai and Tamil suggest that readers of scripts without mirror letters are more susceptible to mirror generalization effects than readers of scripts that do have mirror letters (e.g., Roman script). Importantly, this research suggests that learning to read different writing systems with and without mirror letters may lead to somewhat different cognitive processes.

So far, we have compared reading Tamil and Thai, which do not have mirror letters, to Roman script with mirror letters, but what happens in the case in which a script has a number of mirror letter pairs that have similar perceptual characteristics apart from orientation. Korean Hangul has both lateral and vertical perceptually similar mirror letter pairs (i.e., ㅏ ㅓ, ㅑ ㅕ, ㅗㅜ, ㅛㅠ). It is composed of nonlinear blocks of letters (e.g., 밝은 /balgeun/ ‘bright’). Winskel and Kim (2021) conducted a study to investigate if lateral mirror letter pairs (ㅏ ㅓ, ㅑ ㅕ) have a greater mirror invariance effect than vertical mirror letter pairs (ㅗㅜ, ㅛㅠ). This was based on a study conducted by Ahr et al. (2017), who used a negative priming task with Roman script readers. In the negative priming task, initially, participants judge whether two letters presented as the prime are identical and subsequently whether two household items (e.g., peg, pliers) presented as probes are identical or not. The rationale behind the negative priming paradigm is that if a representation or process (in this case, mirror invariance) is inhibited (e.g., recognizing that *p* and *q* are not the same), then it is more difficult to subsequently activate that process (deciding that household mirror items are the same). Ahr et al. (2017) found that lateral mirror letter pairs (e.g., *p* and *q*) were more susceptible and made it more difficult to inhibit mirror invariance effects than vertical mirror letter pairs (*p* and *b*). Their explanation for these results was that this might be due to mirror invariance being more difficult to inhibit in a lateral than a vertical orientation.

However, when we conducted a similar experiment in Korean Hangul readers, there was no evidence of negative priming due to either lateral (e.g., ㅏ and ㅓ) or vertical (e.g., ㅗ and ㅜ) mirror letter primes (Winskel and Kim 2021). One potential explanation is that Korean Hangul readers may not experience mirror invariance to the same extent as Roman script readers as they are possibly less sensitive to mirror reversals than Roman script readers. This could be due to the relatively more visually complex and demanding nonlinear script-specific characteristics of Hangul. Clearly, additional research is needed to examine mirror invariance effects in other scripts with and without mirror letters.

# Conclusion

The aim of the current chapter was to examine some of the contrasting features of languages and scripts and to what extent they differentially affect cognition in observable and measurable ways. The languages and scripts of the Asian region offer extremely fruitful opportunities for research on language and script-specific effects on cognition and also form useful comparisons with the much-studied European languages and Roman script. Specific reference has been made to the characteristics of the Thai language and its script. Of particular relevance to the focus of this chapter is that Thai is an equipollently framed language with a rich aspectual system, and it has a nonlinear script that does not have mirror letters.

In the original Whorfian or linguistic relativity hypothesis, speakers of different languages have distinct ways of conceptualizing or perceiving the world due to linguistic variation (Whorf 1956). The linguistic relativity hypothesis has been conceptualised in terms of a weaker on-line version and a more pervasive robust off-line version. The weaker version termed *thinking-for-speaking* adopts the view that distinctions in a language that are grammaticized, obligatory, or habitually used, have a channeling effect on attention toward particular functions of these forms during the actual on-line processing of language (Berman and Slobin 1994; Slobin 1996, 2003; Strömqvist and Verhoeven 2004). The stronger version takes the perspective that there are longer term, non-linguistic cognitive consequences of this

linguistic diversity. Thus, effects can be quite subtle or have a more profound or long-term impact on cognition. More recently, script variation has been included in this debate (e.g., Pae 2021).

From this review, we can see that effects on cognition due to language and script-specific variation are, in general, quite subtle and tend to support a weaker, on-line version of the linguistic- or script-relativity hypothesis. Advances in technology are providing us with useful tools for investigating these often quite subtle contrasting effects on attention, and in turn, cognition in different languages and scripts. In order to investigate if there are off-line, longer-term cognitive consequences of this variation, carefully designed studies need to conducted with this overriding goal in mind. As language is the primary system and reading builds on this system, script-specific effects may be subtle or difficult to disentangle from language-specific effects. Future research needs to include other, lesser-studied languages and their scripts so that we can ascertain which are common cognitive patterns or processes and which are shaped by the variation in language or script-specific features. There are many opportunities for future research to be conducted on the diverse Asian languages and their scripts to further investigate linguistic and script-on-cognition effects. One area, for example, that would be worthwhile investigating would be lexical tone variation in languages and their scripts.

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