EXPLORING THE IMPACT OF READING VISUALLY COMPLEX SCRIPTS ON ATTENTIONAL PROCESSES AND VISUAL DISCRIMINATION AND SEARCH SKILLS

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ABSTRACT

The majority of research into differences in visual skills overlooks orthography differences. Instead, they propose that cultural orientation (collectivism or individualism) drives those differences. Orthography in Eastern languages such as Chinese is characterised by intricate strokes which are visually complex. In contrast, orthography in Western languages such as English consists of simple alphabets that are visually simplistic. Our project investigates how reading visually complex orthographies affects visual perception skills. We hypothesised that readers of Chinese will perform better in visual perception tests across all tasks due to their experience with reading visually complex characters in everyday life. A sample of British, Nepalese-British, Chinese-British, Native-Chinese were investigated using a battery of tasks to examine language proficiency and visual skills. Some support for the hypothesis was found. British-Chinese performed fastest in the Visual Search Task, nationality was a significant predictor in the Local feature of the Navon task and reading and writing Chinese were significant predictors in the accuracy scores of the Visual Discrimination Task. Several reasons for the findings are proposed, methodological issues regarding the tasks and suggestions for further research are examined.

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1.0 INTRODUCTION

Our human ability of visual processing is malleable and shaped by elements in our everyday surroundings (Vuilleumier & Driver, 2007). Considering our visual system is moulded by our environment, the language we read likely shapes our visual processes. The Sapir-Whorf hypothesis first put forward in the 1950s proposed that the rules and principles of the language we use impact our perception of the world (Hussein, 2012). However, this theory has been heavily criticised and in more recent years, researchers have developed the Script Relativity Hypothesis which suggests the script we read affects our cognitions (Hoijer, 1954). Some researchers have explored the spatial layout of scripts and their influence on cognition (Winskel, 2022), but there is little to no investigation into the visual complexity of scripts and their influence on attention and visual skills. However, scripts are diverse; if you take a Chinese character and an English word, these two are drastically different. The perceptual learning theory states our responses to stimuli are reinforced by recurrent experience (Fahle, 2004). For example, the more you practice playing an instrument, the better you will be at playing that instrument. This leads us to question, do readers of visually complex scripts have specific attentional processes and advanced visual skills? Previous research has found attentional differences between East Asians and Americans but authors have explained their findings based on cultural differences (Nisbett & Miyamoto, 2005), however, they have not considered key visual differences in the scripts. Thus, this thesis investigates how script impacts attentional and visual discrimination and search skills. We further factor in cultural differences to address previous claims by recruiting individuals from collectivist cultures who have migrated to an individualist culture.

1.1 Understanding the visual complexity of scripts

Writing systems came about over 5,000 years ago, and the first to emerge are thought to be Chinese characters, Hieroglyphs, and Sumerian Cuneiform (Pegado, 2022). Written communication is one of humans' extraordinary inventions allowing the transference of knowledge between generations (Pennington, 2013). At present, there is a significant variation of scripts worldwide. Alphabetic systems such as the Latin alphabet are some of the most common (Ehrich et al., 2013), for example, English, Greek, or Spanish. The alphabetic principle is characterised by grapheme-phoneme mapping (Hanna, 1966); this means sounds are represented by written symbols (See Figure 1). Phonemes are the smallest unit of sound within words, for example, b / a / t are all sounds within the word bat. Whereas, graphemes are written representations of phonemes, for example, the letter k represents the /k/ sound. Also, the letters ck represent the /k/ sound (Francis, 1958). The sounds determine the configuration of letters, this then allows us to obtain meaning from words (Hoosain, 1991).

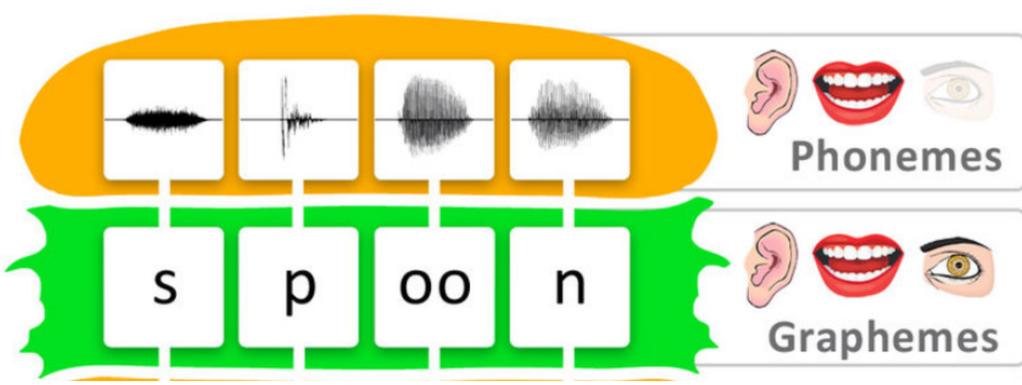


Figure 1. The grapheme-phoneme mapping of the word SPOON. Image retrieved from Fry and Kress (2012).

Similarly, there are other scripts around the world that follow the alphabetic principle. For example, the Nepalese language uses the Devanagari alphabet which has 48 letters and is phonologically based (Bright, 1996). Each letter in the Nepalese alphabet has its own independent and distinct sound so Nepalese words are pronounced exactly as they are written - this is known as transparent grapheme-phoneme mapping. Letters are connected by a horizontal line that runs above the letters creating the word, a gap in the horizontal line signifies separate words (Vaid & Gupta, 2002), for example, नेपाली लेखन are two words. Although we acknowledge the Nepalese script has different linguistic rules, it is an alphabetic script and follows similar reading principles to English. For instance, Nepalese is read from left to right, and words are written based on their phonological arrangement. An example is the word "pen", in Nepalese it is pronounced "Kalama" and written as कलम. The sound "ka" is portrayed by क, the sound "la" is ल and the sound "ma" is म. From this, we understand that letters in the alphabetic script only hold phonetic information and these letters are combined to form words which we extract meaning from. There is no study that has directly investigated Nepalese and English scripts, or compared the similarity between them. For clarity, this project is not focusing on the impact of reading Nepalese script, however, background on the Nepalese script is essential to comprehend our reasoning for using Nepalese participants.

Compared to English and Nepalese, the Chinese language differs sharply from alphabetic languages characterised by the correspondence between letters and phonemes (McBride, 2016). Unlike alphabetic scripts, written Chinese has no grapheme-phoneme correspondence (Tzeng, 2002); for example, the sound "ma" means horse, but the character for 'horse' means horse without any mediation in which the character is pronounced. A saying which is often used to support this theory declares (Biederman and Tsao, 1979), "the image of the character for "horse" is so vivid that one can sense the animal galloping across the page"(Wang, 1973); this is displayed in Figure 2.

Figure 2. The evolution of the Chinese character for the word "horse". Image sourced from Peng (1999).

A Chinese character always holds meaning, whether it's on its own or combined with another character (Shu, Chen, Anderson, Wu, & Xuan, 2003). An average Chinese character is made of 7-12 strokes; a simple character may consist of one or a few strokes, whereas a complex character may consist of 24 strokes (Shu et al., 2003). Correctly identifying characters can be tricky as several characters have visual resemblances in stroke combinations (Luo, Chen, Deacon, Zhang & Yin, 2013). For example, in Figure 3, the two characters are similar in their anatomy, but there is one key difference, 土's first line is short, and the second line is long.

Whereas 士's first line is long, and the second line is short. Both of these characters are commonly used and look almost identical, but they have different meanings (Hua, 2015).

Figure 3. Similar-looking Chinese characters with separate meanings are determined by the length of the stroke or the positioning of a stroke (highlighted in red). Image sourced from an online blog explaining visually similar Chinese characters by Hua (2015).

In addition, a meta-analysis reviewed sixty-four L1-Chinese reading studies, from this Yang et al. (2013) concluded that visual skill and Chinese character recognition ability are significant and positively correlated. So, there is extensive evidence of how imperative it is to differentiate between similar-looking characters (McBride-Chang et al., 2005), Therefore, we speculate whether reading Chinese requires specific attentional and visual skills as opposed to readers of visually simple scripts such as English.

1.2 The Script Relativity Hypothesis

In the 19th-Century, Wilhelm von Humboldt and Johann Gottfried Herder first proposed the spirit of a nation is conveyed through language (Herder & von Herder, 2002); this idea was later developed in the 20th-Century by Franz Boas and Edward Sapir (Koerner, 1992). Sapir proposed that language does not directly reflect reality but has the capacity to shape reality because our linguistic habits unintentionally influence our perception of reality (Hussein, 2012). A student of Sapir's at Yale University, Benjamin Lee Whorf, further developed the theory and proposed that thoughts and behaviours are understood through the linguistic formula of a specific language, and the information is classified in relation to the unconsciously developed language habits of the group (Carroll, 1956). Supporters of the Whorfian hypothesis argue that even linguists with an awareness of structural differences between languages are not able to objectively view their world without the influence of their language (Hussein, 2012). Another student of Sapir's, Harry Hoijer, combined Sapir and Whorf's theories and produced the "Sapir-Whorf Hypothesis" (Hoijer, 1954). The Sapir-Whorf hypothesis predicts language influences an individual's perception of the world since we think in different languages consisting of different linguistic rules (Hussein, 2012). According to the hypothesis, we perceive only what our language allows us to perceive, therefore it controls how and what we view the world, and since there are so many different languages, we all have different world views.

However, this hypothesis is debated; whether or not the language we use completely affects our perception of reality is a topic that requires more research and discussion (Hussein, 2012). The strong version of the hypothesis, also known as linguistic determinism, was held by early linguists before World War II (Boroditsky et al., 2010). This suggested language is a determining factor for our thought patterns and the linguistic categories reflect our cognitive categories. This version has been subject to criticism and has been disregarded by modern linguists (Ahearn, 2021). Compared to the strong version, the weak version proposes linguistic categories and usage can partially influence thoughts and decisions but is not a determining factor (Ottenheimer, 2012). There is supporting evidence for the weaker version of the hypothesis from empirical data (Ahearn, 2012). For example, language regions of the brain have been found to be activated during colour perception tasks (Siok et al., 2009). New studies such as this, have rekindled interest in the theory over recent years (Pae, 2022).

Over five decades, the Sapir-Whorf hypothesis has gone through a constant cycle of acceptance and rejection (Pae & Pae, 2020). Recently, there has been an extension of the linguistic relativity hypothesis of spoken language to the script relativity hypothesis of written language (Pegado, 2022). Pae (2022) emphasises "just like linguistic relativity that postulates that habitual language use results in a unique set of habitual thought and thinking patterns, habitual reading of a particular script has the great potential to yield unique thought processes or patterns in the reader's mind as an embodied experience". The researcher also highlights that differences in writing systems in Asia may account for cognitive differences (of attention, perception, and problem-solving among Japanese, Korean, and Chinese individuals, as well as, differences between Easterners and Westerners. For example, Chinese readers produce shorter saccades and a reduced visual span compared to English readers (Pae, 2022). This is just a snapshot of the differences in visual perception of English and Chinese readers, we continue this comparison later on in the thesis. Yet, we highlight the importance of considering script differences and their impact on cognition (Nakamura et al., 2012).

1.3 Reading Development Theory

Compared to the natural occurrence of spoken languages, written language is considered "artificial" because we need to be taught specific linguistic rules (Gkeka, Agorastou & Drigas, 2019). A reading development theory by Ehri (1991) states that early reading is dependent on visual elements to identify words. This theory was first introduced for alphabetic scripts, but it has also been used to explain the significance of visual processing in reading Chinese scripts (McBride-Chang et al., 2005). Geva and Siegel (2000) observed that primary school children with poor reading abilities made more visual errors where they would confuse two similar-looking letters. This study highlights the dependency we have on visual features when first learning to read.

Further, a deficit in visual processing may be the primary cause of dyslexia in Chinese children. Woo and Hoosain (1984) investigated the performance of dyslexic Chinese school children and non-dyslexic readers in character recognition and visual perception task. The task displayed a series of characters; some were 'distractor characters' similar in shape, sound, or meaning. Dyslexic Chinese readers displayed more difficulty discriminating between similar visual characters, yet no significant difference was found between the groups on auditory tasks. From this, we speculate that dyslexia in the Chinese population may result from visual processing deficits, which further highlights the importance of visual discrimination skills when reading Chinese.

1.4 Differences in Visual Search skills

Humans rely on visual search skills in everyday life (Duncan & Humphreys, 1989), for example, looking for your keys, reading a research paper or even looking for your child in a park. Visual search is a fundamental skill, and visual search tasks are an excellent method to examine the allocation of visual attention (Donnelly et al., 2007; Gerhardstein & Rovee-Collier, 2002; Neider & Zelinsky, 2006). Past studies of visual search have proposed that cultural variations stimulate visual search differences. In cross-cultural studies investigating visual search, American and Japanese preschool children were presented with a 'natural' scene and asked to search for a target amongst distractor objects. Results showed that American children were faster at identifying the target as they appear to have focused and object-based attention (Kuwabara and Smith, 2012). The authors interpret the findings as a result of cultural differences. They claim collectivist countries emphasise collaborative relationships and cooperation between society members, whereas individualist countries accentuate self and independence. However, this project aims to examine the potential role of scripts in visual search, controlling for cultural differences.

When children become literate they get better at processing linguistic stimuli and on a neural level this process initiates specialisation of the Visual Word Form Area (VWFA) which is located in the ventral visual cortex in the temporal lobe of the left hemisphere (Cohen et al., 2002). This is further supported by Duñabeitia, Orihuela, & Carreiras (2014), who investigated the performance of literate and illiterate adults on a perceptual matching task using letter strings. When the position of letters was adjusted, literates were quick to identify them; however, illiterates displayed no awareness of the changes. This finding demonstrates that some visual perception skills are developed through the process of learning to read, especially in the ability to discriminate between visual stimuli. Such findings have led us to question if there is a variation in visual skills between people who read different levels of visually complex scripts.

1.5 Perceptual Learning Theory and hemispheric lateralisation support

Perceptual learning is a process where our sensory systems' response to stimuli is strengthened through experience (Fahle, 2004). The ability to distinguish between different musical pitches or different odours is an example of perceptual learning. Research even shows deaf signers have heightened visual imagery abilities than hearing signers of deaf parents and hearing non-signers (Emmorey, Kosslyn & Bellugi, 1993). The authors of this study explain the enhanced abilities through the linguistic requirements of sign language, such as visualisation. Moreover, a number of studies have displayed an increased ability to discriminate a non-verbal target stimulus with continuous training (Ahissar & Hochstein, 1997; Dill & Fahle, 1998). Although these studies used non-verbal stimuli, from our comprehension of perceptual learning we assume that with prolonged reading experience of a visually complex script would also and the visual complexity of Chinese script, we assume reading Chinese (which involves visual search and discrimination skills) is tied to enhanced visual skills and specific attentional processes.

To support this further, brain imaging studies identified that fixed neural networks of adults brains adjust to reading (Dehaene, 2009), this implies that our brains are rewired to facilitate reading (Pae & Pae (2020). Even professional keyboard players who started at an early age, display more significant and symmetrical primary motor cortices, compared to those who start at a later stage in life (Amunts et al., 1977). Similarly, in the case of languages, differences in experiences are bound to uniquely shape neural networks in the brain. In particular, there are neural network differences when reading and processing different writing scripts, especially between Chinese and English readers, where the script varies significantly in visual complexity. Hsiao & Lam (2013) randomly selected 1000 six-letter English words and 1000 Chinese characters to investigate the visual similarities between them. They found a significantly higher visual similarity between English words as opposed to Chinese characters. This suggests that similar-looking Chinese characters can be challenging to discriminate between, and so reading Chinese requires mastery in visual discrimination and search.

Generally, when processing alphabetic languages, fMRI studies have displayed activation in a segment of the left fusiform gyrus, which has been labelled the Visual Word Form Area known for specific word responses (McCandliss, Cohen & Dehaene, 2003). On the other hand, the right occipital cortex is associated with identifying visual and spatial recognition of objects, and there are activations in the right cerebral hemisphere when reading Chinese characters (Tzeng et al., 1979). Chinese characters hold more spatial knowledge and stroke position information; hence, it requires more visual analysis. In a visually complex script like Chinese, its characters are derived from pictograms hence activating the right occipital cortex because it requires similar visual and spatial recognition (Perfetti, Tan & Siok, 2006). If such profound effects are made in our neural networks from reading these languages, the effects may also govern the differences found in behavioural studies.

Furthermore, researchers have investigated Japanese which entails both visually simple scripts (Hiragana & Katakana) and visually complex scripts (Kanji); Hiragana and Katakana are phonetic and syllabic, whereas Kanji incorporates logographic similar to Chinese characters (Österman, 2018). The three scripts are used in the following ways: Hiragana is used grammatically to write endings of verbs, adverbs, and adjectives, Kanji is used to write nouns and the stems of verbs, adverbs, and adjectives, whereas Katakana is used for technical terms or foreign words (Lambe, 2019). Neuroscientific studies of Japanese provide additional support for the hemispheric lateralisation of alphabetic and logographic languages. When Japanese participants were presented with syllables of Hiragana and Katakana unilaterally, they displayed activations in the right visual field of the left hemisphere (Hirata & Osaka, 1967). However, when asked to report Kanji characters on a screen, activations in the left visual field in the right hemisphere were found (Hatta, 1977). Recent fMRI studies have found that the occipitotemporal cortex is activated in the right hemisphere in Kanji naming tasks. However, when naming Katakana phonograms, the left hemisphere lateralisation was activated (Nakamura et al., 2005). Therefore, these findings from the Japanese language give substantial support to hemispheric lateralisation where the left is utilised in visually simple scripts, and the right is operated for visually complex scripts. Such anatomical differences highlight the neural plasticity of networks shaped by one's language experiences, further emphasising the need to investigate visual skill differences between readers of different visual complexity writing systems.

1.6 Differences in attentional processes (global vs. local)

As seen in Figure 3, the complexity of Chinese characters demands visual attention allocated to all aspects of the character (top, bottom, left, and right). Thus, we would assume that Chinese readers would have a global attentional bias to process all aspects of the character. However, research into visual attention, whether we locate our attention locally or globally, also uses cultural orientation to account for differences found (Nisbett et al., 2001). In a study by Masuda and Nisbett (2006), participants were asked to spot the differences between two images in a flicker paradigm. The original image was repeatedly transformed and displayed in a sequence. The images' difference was at a focal (in the object) or contextual level (surroundings of the object). American participants performed better when detecting changes at the local level, whereas East Asian participants were better at detecting changes at a global level. According to cultural studies, Easterners observe the connections between the object and contexts surrounding it due to their collectivist culture yet, Westerners adopt individualistic processes and perceive displays by observing prominent objects in the visual field irrespective of the context (Nisbett & Miyamoto, 2005). Again, these authors account for findings from a cultural orientation perspective: Easterners have a global bias and Westerners have a local bias. However, this conclusion does not consider another likely influencer of visual processing, i.e., visual differences in script. Thus, we aim to explore whether culture or the visual complexity of the scripts drives attentional differences.

Finally, Davidoff, Robertson & Shapiro (2002) investigated the Himba people of Northern Namibia; these people do not have a written language and live by fixed social norms (Crandall, 2000). Davidoff, Robertson & Shapiro (2002) discovered striking findings where the Himba people displayed extreme focal attention in the Ebbinghaus Illusion task; the task requires participants to judge the relative size of an optical illusion comprising two circles, one surrounded by large circles and the other small circles (De Fockert, Davidoff, Fagot, Parron & Goldstein, 2007). The Himba people were able to focus on the target successfully and simultaneously disregard the context and displayed the least illusion effect out of any other group (autistic children or men), signifying the extremity of their local bias. Western participants showed a greater global preference than the Himba population. The study concludes the results are driven by cultural differences; however, we propose an alternative account concerning scripts.

To elaborate, we assume Davidoff, Robertson & Shapiro's (2002) findings convey the human tendency to process information locally. We speculate that when we start to learn a particular script, our attention field begins to shape according to the specific visual demands of the written language. To explain further, the Himba people have no written language; thus, they may not develop global attention fully. To read, an element of global attention is needed. The Himba people show extreme local attention because they do not read any written language that requires global attention attending to words and characters. Although the authors claim these attentional differences result from a cultural effect, they can potentially be explained by visual complexity differences in the script. Although we do not directly test readers and non-readers in our study, the above findings lead us to solidify our question: Are attentional differences a result of experience reading visually complex scripts and visually simple scripts? More specifically, do Chinese readers have a greater global bias than non-Chinese readers?

Despite all the recognition of the significance of visual processes in Chinese reading, there is insufficient research into attentional and visual processes that contribute to reading Chinese characters. The literature commonly assumes that visual differences are derived from cultural influences: whether participants come from individualistic or collectivist cultures (Nisbett & Miyamoto, 2005; Masuda & Nisbett, 2006; Kuwabara and Smith, 2012). However, the differences in the visual complexity of language and its influence on visual skills should not be overlooked. Thus, we assume that global attention and enhanced visual discrimination and search skills play a significant role in reading Chinese compared to other scripts.

1.7 Addressing the culture debate

Considering there are alternative cultural explanations for attentional and visual skills differences, we wanted to consider the cultural orientation of our participants and investigate its influence. We believed we could do this by recruiting culturally diverse groups (individualistic and collectivist) with visually simple scripts and visually complex scripts. Therefore, we recruited Chinese-British and Nepalese-British participants. These participants and their families originate from collectivist cultures, yet they have grown up in an individualistic culture in England.

There is much dispute behind the cultural identity of younger generations of ethnic minority groups regarding citizenship, security, and community cohesion (Finney and Simpson, 2009). Generally, the ability to speak fluent English is considered an indicator of being successfully integrated into British society (Blackledge, 2009). Naturally, earlier generations of Chinese migrants experienced language barriers (Mau, 2014); however, children of migrants who have grown up in British society became English monolinguals or English-dominant bilinguals (Wei, 1994) and undergo a decline in the Chinese language (Modood et al., 1997). The Fourth National Survey of Ethnic Minorities revealed a significant decline in the Chinese language and a more significant decline within the South Asian sample (Modood et al., 1997). Although there is no similar research for Nepalese-British individuals, the majority of second-generation migrants tend to follow this pattern of language development. Since the author is Nepalese, the Nepalese-British group was appropriate for this research project.

The 'typical' understanding of culture is that it is fixed and static. It is defined by Jackson (1999) as a 'set of patterns, beliefs, behaviours, institutions, symbols, and practices distributed and preserved by a group of individuals connected by an ancestral heritage and a concomitant geographic reference location.' However, the way one's cultural identity is developed is much more complex, especially for migrants. An example of this is the Chinese-British group in England; the group is characterised by a complex mix of ethnicity, language, class, and cultural and professional differences. Therefore, compared to Chinese communities in China, the Chinese-British population does not form the typical cohesive, integrated communities found in countries of origin. In that case, culture can be approached as malleable. Post-structuralists described culture as fluid and created by passion and morality (Foucault, 1972). Identities are associated with one's culture and traditions; these are either historical or recent inventions. Many cultural theorists explain the malleable and shifting nature of 'culture' (Anthias, 2001). There are now novel understandings of the development of cultural identities where explanations focus on shared experiences rather than factors to do with an individual's origin (Mau, 2014).

This study recruited Chinese-British pupils who are not recent migrants from Hong Kong/China. Their parents were born or raised in Hong Kong/China, but they were born or raised from a young age in the UK. In this study, the participants more proficient in the English language and secondly in Cantonese/Mandarin are collectively called 'Chinese-British'. We understand that Cantonese uses the traditional Chinese script and Mandarin used the simplified Chinese script and that they vary in visual complexity. However, both scripts are similar and regardless of the term “Simplified Chinese”, it remains more visually complex than English or Nepalese. Furthermore, a meta-analysis of 34 studies published from 1991 to 2011 investigated the relationship between visual skills and Chinese reading acquisition. The studies recruited participants from both Mainland China and Hong Kong and they found no regional differences between the groups in the studies they analysed (Yang et al., 2013). Our rationalisation was that our Chinese-British participants would be more culturally tied to British culture than Chinese culture even though they read different versions of Chinese and come from different countries. Thus, we attempted to measure individualism and collectivism scores through a cultural assessment. This assessment explores two orientations of Individualism and Collectivism: the vertical orientation focuses on hierarchy and the horizontal orientation focuses on equality (Triandis & Gelfand, 1998).

Similarly, we speculated Nepalese-British participants were more culturally tied to

British culture than Nepalese culture; again, this was operationalised through a cultural assessment. Participants who are more proficient in English and secondly in Nepalese are collectively called 'Nepalese-British'. However, the label cannot sufficiently represent the diverse ethnic and cultural heritages affiliated with these individuals. In the coming chapters, the term 'Chinese-British' is loosely applied to these young people of Hong Kongese and Chinese descent, and the term 'Nepalese-British' is loosely applied to these young people of Nepalese descent, despite the extent of their connections with their/their parents' country of origins. Earlier on, we explained the Nepalese script in terms of its similarity to English, but our Nepalese-British participants had poor Nepalese reading ability. We used Nepalese-British participants to explore the influence of collectivist culture yet only have experience reading visually simple scripts. These individuals cannot read Chinese, therefore, are grouped as “non-Chinese readers” alongside the British group.

1.8 Aims of the Research Project

This research project aims to investigate the impact of reading visually complex scripts on attentional processes and visual discrimination and search. These differences are essential to consider and understand as they have implications for reading models, education policies, and understanding for people worldwide. Especially because being able to speak more than one language is becoming a necessity in the world of increased globalisation.

1.9 Hypotheses

In this thesis, we aim to investigate differences in attention, visual discrimination, and search abilities between readers or visually simple alphabetic scripts and visually complex logographic scripts. We will focus on the attentional bias (global or local) using the Navon Task and two visual skills of discrimination and search using the Visual Discrimination Task and Visual Search Task. We present our hypothesis of each task between each independent groups: British, Nepalese-British, Chinese-British, and Native-Chinese participants

Global or Local Attention

Hypothesis 1: Chinese readers (British and Native) will display a global bias compared to non-Chinese readers (British and Nepalese).

This hypothesis stems from our understanding of Chinese characters and how each stroke holds meaning. Because the perception of global features is crucial when reading Chinese, our hypothesis was that Chinese readers and non-Chinese readers significantly differ between analytic (local) and holistic (global) attention types.

Visual Discrimination

Hypothesis 2: Chinese readers (British and Native) are faster and more accurate at discriminating between similar visual patterns than non-Chinese readers (British and Nepalese).

This hypothesis is based on our understanding that reading Chinese requires discrimination between visually similar characters. This is important as making a mistake when discriminating between visually identical characters can drastically change its meaning.

Visual Search

Hypothesis 3: Chinese readers (British and Native) are faster and more accurate at searching for a target amongst distractors than non-Chinese readers (British and Nepalese).

Similarly, to visual discrimination, searching for different elements of a character to obtain its meaning requires an advanced level of visual search. Chinese readers also need to be fast at searching for specific elements of the character so they can read efficiently.

2.0 METHODS

The study was accepted by the STEM Ethics Committee at the University of Birmingham (ERN_14-0279).

2.1 Participants

The experiment was carried out with 83 participants (39 males, and 44 females). The age range was 18 - 27 years (M = 21.8, SD = 2.32). All participants had normal or corrected vision with glasses or contact lenses. Participants received 5 GBP or 1.5-course credits for taking part in the study. All participants were fully informed about the procedures and their rights as a participant, and prior to testing informed consent was obtained (see Appendix A). After the experiment, participants were debriefed on the aims of the study (see Appendix B).

2.1.1 Participant groupings

Participants were grouped based on their language background determined by the Language History Questionnaire version 2.0 (LHQ, See Appendix C) (Li, Zhang, Tsai & Puls, 2013). There were four groups: 21 British, 20 Nepalese-British, 21 Chinese-British, and 21 Native-Chinese. The British, Nepalese-British and Chinese-British participant groups were all fluent in English as determined by the Language History Questionnaire. The British participants were either English monolinguals (N=8) or fluent in European languages such as French, Spanish, or Welsh with an orthographic system similar to English (N=13). Reading and writing scores were derived from the Language History Questionnaire mentioned below. Participants scored out of 0 and 7 on their abilities in reading and writing in their L1 and L2, 0 being none at all and 7 being fluent. Their reading score for European languages ranged from 0 to 7 and the average reading score was 3.5. Writing scores ranged from 0 to 7 and the average writing score was 2.8. The Nepalese-British Bilinguals were second-generation Nepalese people who grew up in the UK as a result of their families immigrating from Nepal in the early 1990s due to their fathers serving for the Gurkha regiment in the British Army. These individuals are fluent in all aspects of English and have some experience in Nepalese, however, English remains their dominant language. The group's Nepalese reading score ranged from 0 to 7 and their average was a score of 2.6. Further, the group's Nepalese writing ability ranged from 0 to 5 and the average writing ability score was 2.2.

The Chinese-British group has a similar language background to the Nepalese-British group. They are second-generation Chinese individuals whose families immigrated from Hong Kong/China. Similarly to the Nepalese-British participants, English is their dominant language and they are fluent in reading/writing/speaking English, but their experiences vary in reading/writing/speaking Chinese. Mandarin and Cantonese use the same Chinese orthography, the only difference is that Cantonese uses Traditional Chinese and Mandarin uses Simplified Chinese. Simplified Chinese is a visually simplified version of Traditional Chinese, thus for this thesis, the term Chinese is representative of Cantonese and Mandarin. The group's Chinese reading score ranges from 0 and 7 and their average Chinese reading score was 3.9. In writing, the scores ranged from 0 and 5 and their average Chinese writing ability score was 3.1. The fourth group was Native-Chinese participants from Hong Kong/China, these individuals were fluent in speaking, reading, and writing Chinese and English, however, English was their less dominant language. The group's English reading score ranges from 3 and 7 and their average English reading score was 5.5. In writing, the scores ranged from 3 and 7 and their average English writing ability score was 4.8.

2.2 Materials

A computerised version of the NAB Visual Discrimination Task was created on PsychoPy version 2020.1 (Peirce et al., 2019) and hosted on Pavlovia (https://www.pavlovia.org/). Additionally, an online platform, PsyToolKit (Stoet, 2010; 2017), was used to remotely carry out Corsi-Block Tapping, Visual Search, and Navon Task.

2.3 Experiment Design

Participants completed two questionnaires, the Language History and Culture Orientation Questionnaires prior to the computer tasks. The computer tasks were completed in the following sequence: Visual Discrimination Task, Corsi-Block Tapping, Visual Search, and Navon Figure Task. All participants completed all tasks in the same order. The dependent variables were reaction time (ms) and accuracy (% correct) in the Visual Discrimination Task, Visual Search, and Navon Figure Task.

2.4 Procedure

Initially, the experiment was to take place in the Thompson Lab and the University of Birmingham. However, due to the COVID-19 pandemic, the assessments were moved online and administered through Pavlovia and PsytoolKit links. Thus, participants carried out their tasks in the comfort of their own homes. Participants were asked to complete their tasks in an environment that would ensure optimal performance (e.g., a private room with no extraneous noise).

Participants were recruited through opportunity sampling using social media platforms such as WeChat, Instagram, and Discord. Once recruited, the participants chose one of the given time slots to carry out the computer tasks online. Before each task, the researcher thoroughly explained the instructions. For further understanding, screenshots of practice rounds of each task were also sent. Each participant took around 1- 1.5 hours to complete all tasks. More detailed procedural information for each task is described in the sections below.

2.4.1 Language History Questionnaire (LHQ)

The LHQ explores the linguistic background of participants, and it was administered through a link on GoogleForms. The questionnaire investigates language proficiency, the context, and habits of language use, of multiple languages. This also includes questions on the dominance of the cultural identity of the languages concerned (Li, Zhang, Tsau & Puls, 2013). The questionnaire is divided into two sections and contains a total of 22 items: the first section begins by asking the participant for necessary details (Name, email address, and contact number). Then, significant questions about language history (Items 1 - 13) are examined, starting with how many and which languages are used by the individual. Next, the questions focus on assessing the proficiency of each language in terms of reading, speaking, listening, and writing abilities.

The project investigates visual skills; therefore, only questions about reading were inspected. Some examples of these consist of: 'List all the languages you know or have studied. List in order from your strongest (most proficient) language to your weakest language (least proficient).' or 'At what age did you start using each language in terms of reading?'. To identify their reading and writing abilities, we used the question "Rate your current ability in each of the languages you have studied or learned in terms of speaking, reading, writing, and listening." for their L1 and L2. Participants chose a score between 0 and 7 to represent their abilities in reading/writing, 0 represented 'no ability', and 7 represented 'like a native'. The complete set of questions can be located in Appendix B, however, we only used answers for the questions that were useful to the project.

2.4.2 Culture Orientation Questionnaire (COQ)

Participants completed the COQ (See Appendix D), designed to measure the four scopes of collectivism and individualism; it was also administered via GoogleForms. The scale consisted of 16 items including statements such as 'I'd rather depend on myself than others.', 'It is important that I do my job better than others.', 'If a co-worker gets a prize, I would feel proud.' and 'Parents and children must stay together as much as possible. Responses were marked on a 9-point scale where 1 expressed 'Never or Definitely No' and 9 expressed 'Always or Definitely Yes'. The scale explores the different dimensions of individualism and collectivism, in terms of social relationships. For example, whether they value equality, referred to as 'horizontal', or whether they consider hierarchy, referred to as 'vertical'. Horizontal Individualism (HI) is seeing the self as distinct from the group; they value autonomy and are incredibly self-reliant. Although they value equality and are not interested in attaining high status. Vertical Individualism (VI) on the other hand, values autonomy, but unlike HI, they recognise and accept the inequality between individuals. Therefore, these individuals prioritise high status and individual competition. Horizontal Collectivism (HC) views the self as part of a group; they see themselves and the members of the group as interdependent. These individuals may not respond well to authority as they place high importance on equality. Lastly, Vertical Collectivism (VC) views the self as part of the group. However, they recognise and accept the inequality between groups. These individuals value the sincerity between members of their ingroups. They are ready to surrender individual goals for the benefit of their group, especially if there is competition with out-group members.

These four scopes of collectivism and individualism have been defined based on four attributes: first is the definition of the self in terms of the emphasis on personal or collective aspects (Triandis, 1989). The second is based on individual goals; this may be either more or less important than group goals (Yamaguchi, 1994). The third is the importance of exchange instead of a 'communal relationship' (Clark & Mills, 2012) or the importance of rationality rather than relatedness (Kim et al., 1994). Lastly, the fourth attribute is the emphasis on one's social behaviour and how their attitude and norms act as causes. Although the four scopes were not relevant to our research, the questionnaire explored both individualism and collectivism domains in depth. Thus, we combined the horizontal and vertical individualism scores to calculate a total individualism score and the same to calculate a total collectivism score. The questionnaire investigated the cultural standpoint of each group, considering the culture of Nepalese-British and Chinese-British participants at home is different from the culture of society.

2.4.3 Corsi-Block Tapping Task - Control Task

The Corsi Block-Tapping test is a measurement of short-term visual-spatial memory (Kessels et al., 2000); it was implemented on an online psychological experiment platform called PsyToolKit (Stoet, 2010; 2017). Kessels et al. (2000) study identified that healthy adults have an average block span of 6.2 blocks and healthy functioning individuals are likely to have a block span between 5 and 7 blocks. We expected participants to score within this range.

In the task, participants view a display with nine purple blocks (see Figure 4a). These purple blocks turn yellow one after the other in a random sequence (see Figure 4b), at first, only two blocks turn yellow, gradually the number of blocks that turn yellow increases, and the task becomes more complicated. The task is to click the blocks in the sequence identical to the one presented after hearing the word ‘GO’. Once the participant is finished clicking the correct sequence, they indicate this by clicking ‘DONE’ on the bottom right-hand corner. A pink feedback block on the bottom right-hand corner displays a smiley face or frowning face for correct and incorrect responses respectively. If the sequence is clicked in the wrong order, participants get another trial at the same level, but if they are incorrect again, then the Corsi block score is calculated and displayed. The task took approximately 3-4 minutes to complete.

a) b)

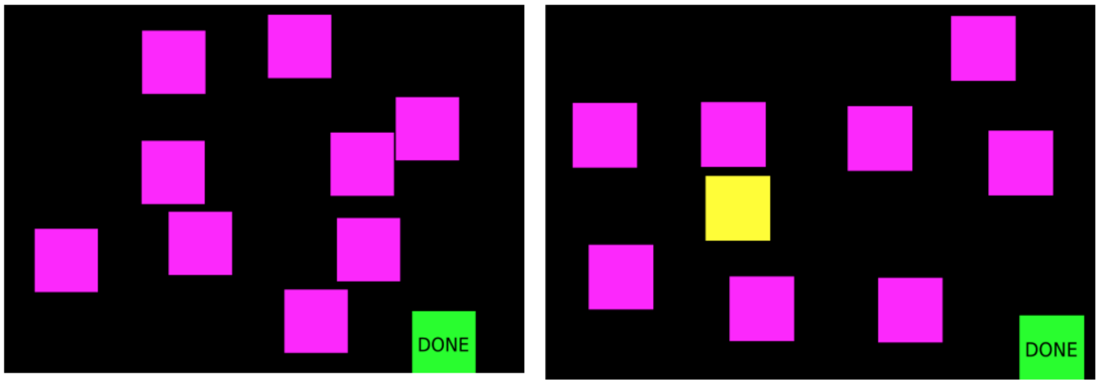


Figure 4. a) The Corsi-Block Tapping Task display containing the nine purple on the screen. b) The Corsi-Block Tapping Task display with one of the purple blocks changed to yellow.

2.4.4 Visual Discrimination Task (VDT)

The Visual Discrimination Task is a component of the Neuropsychological Assessment Battery (NAB) created due to the lack of assessment instruments that were capable of providing sophisticated data within a short administration period (Benton, 1994). The NAB Visual Discrimination Test is based on the visual match-to-target paradigm; it is used to measure visual perception. Unlike other visual perception tests (e.g., Visual Form Discrimination Test), it uses stimuli that cannot be verbally encoded such as nonsense shapes and figures. The test uses an 18-item visual match-to-target task where the participant is required to match a target visual design from an array of four similar designs which are presented beneath the target. The administration time is approximately 5 to 10 minutes. This test is used initially to investigate the level of visual impairment in visually impaired individuals. However, we used the stimuli and created an online computer version where participants are required to hit the correct response key after identifying the matching stimuli.

The computerised version of the test was created using the PsychoPy builder view. Through this, we could measure reaction time. To create the task, the visual stimuli books 1 and 2 from the NAB Visual Discrimination Task were scanned and uploaded onto a computer. Each page of the book was uploaded onto the Procreate app on an iPad to change the response from A B C D to the keyboard responses R, U, C, and N (see Figure 5) because they spatially matched the choices on the screen, assuming it would be easier for the participant instead of having to memorise different response keys. After this, each stimulus on the page (five per page) was then digitally cut out and saved individually to be uploaded on PsychoPy.

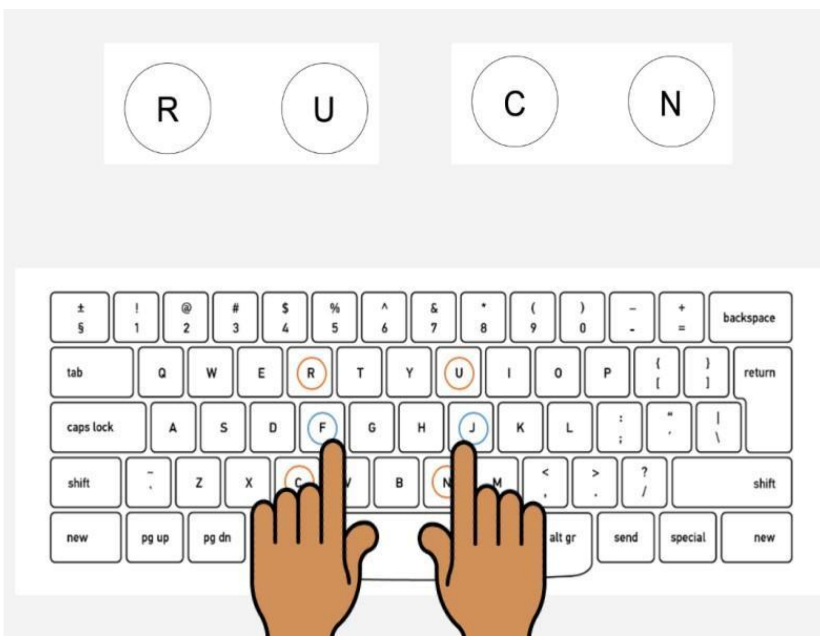


Figure 5. Spatially matched keyboard responses and finger positioning for the Visual Discrimination Task.

The VDT task was divided into four equal blocks (see Table 1). The first two blocks were practice blocks and the last two were testing blocks. There were 20 trials in total for the first two blocks, participants practiced hitting the response keys for the first 8 trials. In these trials, letters R, U, C, and N would appear randomly, and all participants had to do was practice hitting these keys. The remaining 12 trials were used to familiarise participants with the main VDT task. We created a task similar to the VDT using Hebrew and Arabic words (see Figures 6a and 6b); participants had to match the target words with one of the four choices by hitting the correct response key. No participants had experience in either Hebrew or Arabic; therefore, the words are processed shapes with no meaning.

Blocks	Description	Time Taken
Keys Practice (see Figure 5)	Practice hitting the response keys	1-2 minutes
Task practice (see Figure 6)	Practice matching task with Hebrew and Arabic words	1-2 minutes
VDT Part 1 (see Appendix E)	The matching task with Stimulus Book 1	7-10 minutes
VDT Part 2 (see Appendix F)	The matching task with Stimulus Book 2	

Table 1. The structure of the Visual Discrimination Task displays what the four blocks consisted of and the time taken to complete each block.

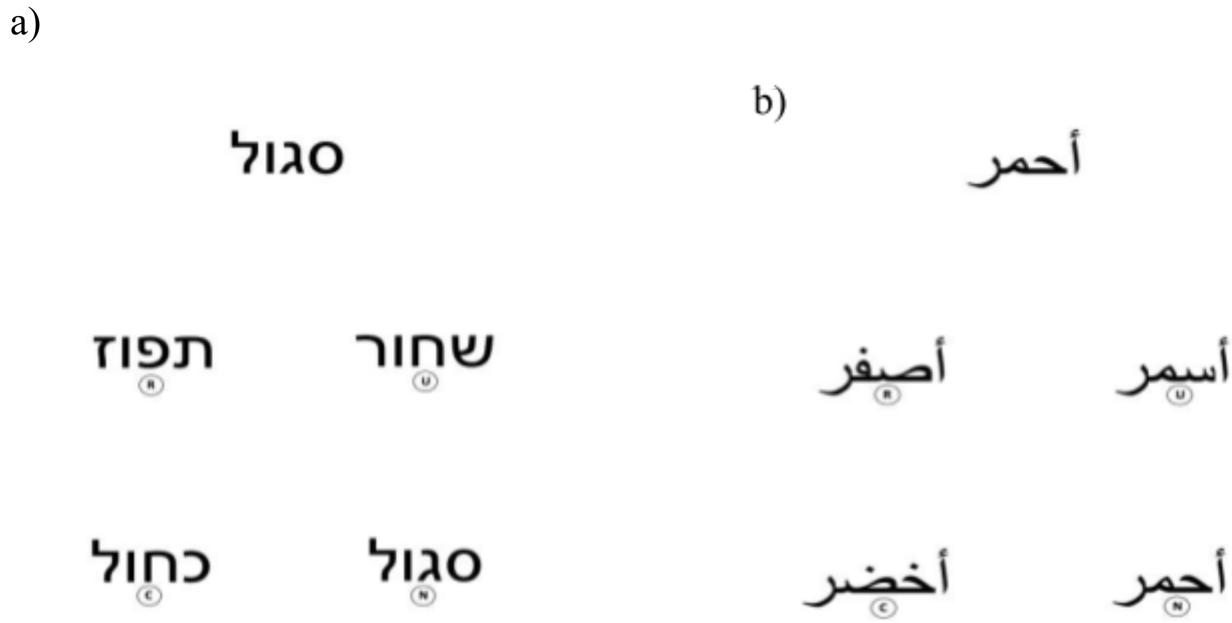


Figure 6. The second practice block of the Visual Discrimination Task involves a) Hebrew words and b) Arabic words.

After the practice block, participants are presented with the main section of the task (See Figure 7). In total there were 36 trials, the trials are split into 2 blocks with 18 trials in the first using stimuli from Stimulus Book 1 (see Appendix E) of the VDT and the other 18 trials of the stimuli using Stimulus Book 2 (See Appendix F) of the VDT. Each stimulus book differs in the visual items. Between each block, short breaks were offered to refresh their eyes and hand muscles. Before the next section began, participants were reminded to respond by hitting the correct keys on the keyboards as fast and accurately as possible.

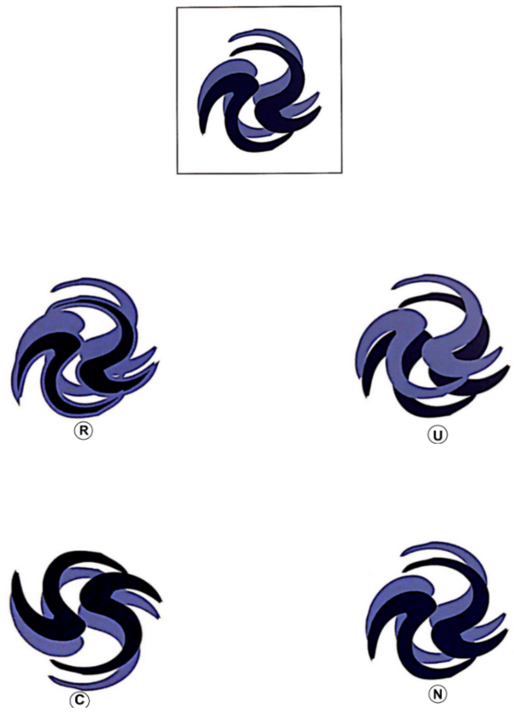


Figure 7. A display in the Visual Discrimination Task with target visual design (in the box) and an array of four visually similar designs.

2.4.5 Visual Search Task

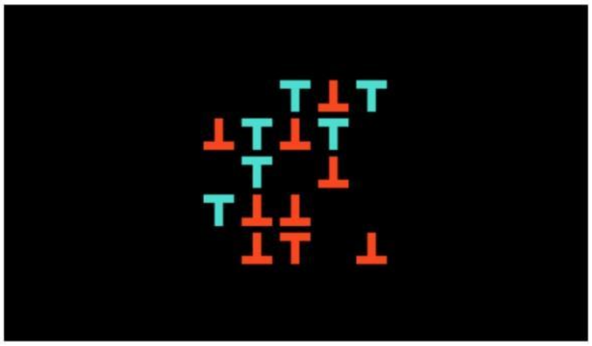
The Visual Search Task requires the participant to locate a visual 'target' amongst distractor items (Wolfe, 2003). In our task, the display comprised a target letter T among an assorted number of other T letters, and participants were instructed to find the target letter (see Figure 8a). To make the search more difficult, the distractor letter T's varied on two different levels: colour and orientation (0, 90, 180, and 270 degrees). There were 5, 10, 15, or 20 distractors present; this was randomised in each trial. The participant's goal is to find an orange letter T at 0-degree orientation, the target was always orange. The width and height of all items (target and distractors) were 0.86 degrees. There were 50 trials in total, and the task took approximately 5-6 minutes to complete.

Participants were instructed to hit the "SPACEBAR" key on the keyboard when spotting the target letter, for example in Figure 8b. However, if the target letter was not present, such as in Figure 8c, participants must refrain from hitting the "SPACEBAR" key. The dependent variable was reaction time (ms) and accuracy (number of errors). If participants took more than 4 seconds to respond then, they would be presented with feedback: 'There was one, but you did not respond' (Figure 8d). Following the feedback, a new display would be presented.

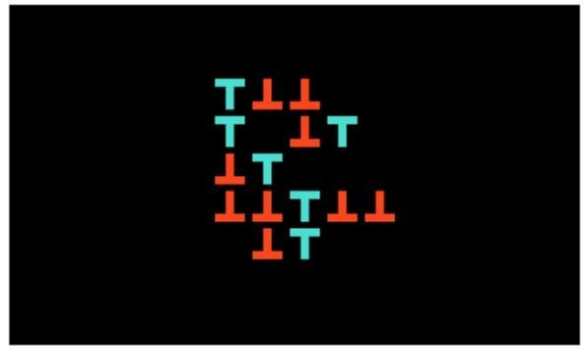
Past studies of Visual Search have traditionally used reaction time and accuracy as dependent measures (Bundesen & Pedersen, 1983; Boot, Becic & Kramer, 2009; Wolfe, Palmer & Horowitz, 2010). We have imitated conventional research and measured reaction time and accuracy to determine search behavior. The task was administered on PsyToolKit (https://www.psytoolkit.org/), a readily available website for psychological experiments for educational research purposes without needing further permission (Stoet, 2010; 2017).

a)

b)



c)



d)

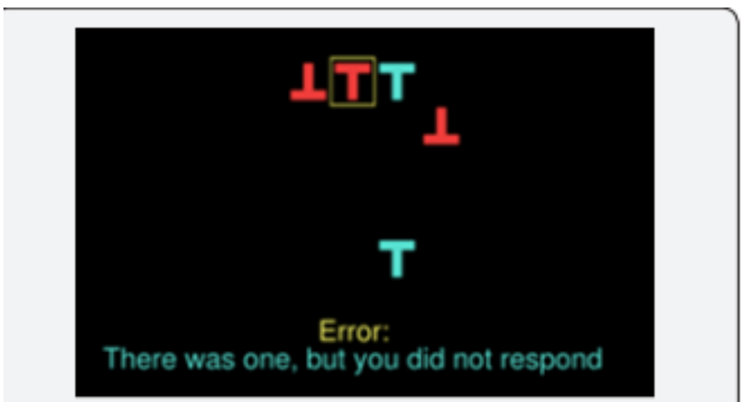


Figure 8. a) The instructions are presented to display the target letter and distractors in the Visual Search Task. b) Search display with target present. c) Search display with target not present. d) Error message presented when participants did not respond correctly to the target letter in the search display.

2.4.6 Navon Task "Forests before trees"

The Navon task (Navon, 1977) is a classic tool to investigate attentional processing style by measuring the speed of global and local information processing (Hildenbrand, 2020). The basic understanding behind Navon's research is that individuals have contrasting cognitive styles: holistic or analytic. Holistics often pay attention to large-scale patterns whereas analytics tend to associate individual fragments and their connections (Navon 1977). So when objects are arranged in large groups, those with a holistic cognitive style are likely to attend to global features and those with analytic cognitive styles are likely to attend to local features.

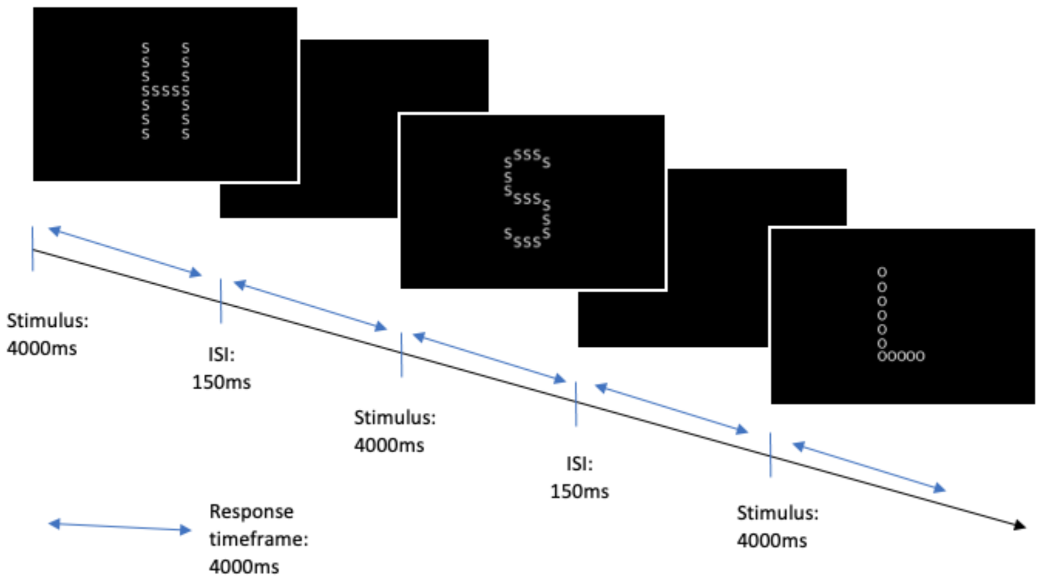


Figure 9. Example trials composed of a 150 ms inter-stimulus interval (ISI) followed by the stimulus presented for a maximum of 4000 ms. Participants responded as quickly as possible within the 4000 ms timeframe.

The computerised version of the task was administered on Psytoolkit (Stoet, 2010, 2017) and took approximately 5 minutes to complete. There were 50 trials and each display consisted of large letters made up of small-sized letters. Participants were informed of the target letters (H or O), in some trials, the target letter appeared on a global level (see Figure 10a) and sometimes on a local level (see Figure 10b). Participants got up to 4 seconds to respond to target letters. Sometimes, the display would have no target letters on either level (see Figures 10c and 10d). To indicate whether or not they saw a target letter (H or O), participants responded by pressing the key 'B' if the target letter was present, or key 'N' if the target letter was not present. Feedback was given straight after a response was made, for example, “too slow” “wrong” or “correct”. The average reaction time (ms) and proportion of errors (number of incorrect responses) on displays with global targets were the dependent variables. Participants were instructed to respond quickly yet accurately since a poor level of global processing was understood as a longer reaction time and a greater number of errors.

a) b) c) d)

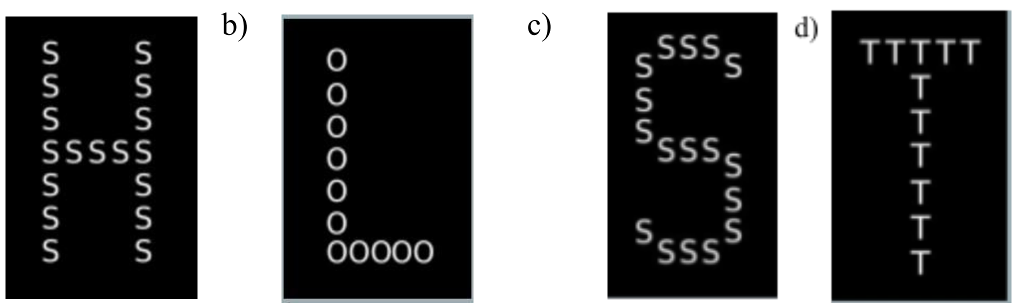


Figure 10. a) A Navon display with the target letter H on a global level made up of the letter S at a local level. b) A display with the target letter O on a local level making up the letter L at a global level c) A display with no target letters present, the letter S comprising both local and global levels. d) A display with no target letters present, the letter T comprising both local and global levels.

<u>*2.5 Impact of COVID-19*</u>

In March 2020, when the UK government announced the first national lockdown, universities, and workplaces were closed for safety measures. As a result, my experiments which were initially supposed to be run at the university had to be relocated online. Therefore, it took time for me to learn how to run the experiments online and administer them through a link. As many other students had to resort to this, our university purchased a Pavlovia license to run online experiments. Converting the tasks onto the Pavlovia website and planning ways to implement the experiment online significantly delayed my project. It was also more challenging to find participants because first and second-year students were no longer required to achieve credits through research participation. Regardless, I strived to find participants through social media platforms during the first 4-month lockdown and managed to find a sufficient amount to carry on with my project.

2.6 Data analysis materials: Linear mixed effect models

Initially, we tested whether the tasks could be combined into a single factor using factor analysis. However, our independent variables were measuring different constructs, for example, attentional bias, visual discrimination, and visual search, therefore this method was considered unsuitable. Although they were different tasks, there were significant correlations between the tasks (see Table 7). Therefore, the linear mixed model (LMM) method of analysis was considered most appropriate to analyse the data for the following reasons: Firstly, LMM is a statistical model that can analyse data with correlated observations (Yu et al., 2021). By modeling the correlation structure of the data, LMMs are able to reduce the chances of inflated p-values providing more accurate results. A common reason why p-values might be inflated is because of the presence of correlated data. In this case, an LMM could be used to control for this correlation and reduce the inflation of p-values. To further avoid the chances of inflated p-values, such as from multiple comparisons, statistical methods such as Bonferroni adjustments were applied to control for the overall Type I error. Secondly, with

LLMs, we are able to specify random effects (such as participants) and divide the variance, instead of grouping the variance into an error. Thirdly, LMMs are capable of dealing with missing data since they can use all the available data to estimate model parameters and make predictions, compared to traditional ANOVA which would reduce the sample size resulting in reduced power of the analysis (Krueger & Tian, 2004).

Overall, LMMs offered more flexibility and advantages and so it was considered most appropriate for our project. The use of Linear mixed models (LMM) is also getting more common and is becoming a substitute for the classic repeated-measures ANOVA (Magezi, 2015). We used the lmer() function to analyze the response time and accuracy. Thus, the lme4 package in the R software was operated to fit all models (Bates, Maechler, Bolker & Walker, 2014). The significance was computed using the lmerTest package, which applied Satterthwaite's method to calculate degrees of freedom and generate p-values (Kuznetsova, Brockhoff, & Christensen, 2017).

3.0 RESULTS

We begin by presenting the cultural orientation and the language history of the participants. Then we examine the effects of nationality, reading and writing Chinese, or reading and writing other languages (alphabetic) on reaction time and accuracy in the three tasks: Navon, Visual Discrimination, and Visual Search Task. Finally, we present the correlations between the tasks.

3.1 Data cleaning and exclusions

In order to reduce errors and improve the accuracy of parameter estimates, we took appropriate action to remove incorrect and extreme scores. First, we calculated the average reaction times (RTs) for each task and participant. Then, we excluded any trial with a difference of more than 2

SD from the average RT for that particular participant. Further, we excluded participants with less than 50% accuracy from the VDT task (N=4, all from the British group). One participant in the Chinese-British group only completed two experiments (Corsi-Block and Visual Discrimination), so their data were included in these analyses only.

3.2 Corsi-Block Tapping Task - Control Task

All participants performed the task following the instructions. In Table 2, the means and standard deviations for the Corsi Block Tapping Task are presented. The British group had the lowest average block span and the Nepalese-British had the highest. However, all averages fit in with the 5-7 block span outlined in previous research (Kessels et al., 2000). A One-Way ANOVA was also completed in order to see if there were any statistical differences between the four groups. The results showed that the groups were not statistically different from each other ($p>.05$).

Group	*M*	*SD*
British (N=12)	5.67	1.59
Nepalese-British (N=19)	6.30	1.30
Chinese-British (N= 20)	6.24	0.77
Native-Chinese (N=21)	6.05	2.16

Table 2. Table displaying the means and standard deviations in the Corsi Block Tapping Task.

Culture Orientation Scale (COQ)

Across all groups, the Individualism scores ranged from 32 – 66. The British group had an average score of 48.1 (ranging from 34 and 64), the Nepalese-British group had an average of 49.3 (ranging from 32 and 60), the Chinese-British group (ranging from 32 and 61), and the Native-Chinese group (range from 33 and 66) both had an average of 50.3. In Figure 11, the averages of individualism scores between groups are displayed in a bar graph. Similarly, across all groups, the Collectivism scores ranged from 33 – 68. The British Group had an average score of 52.6 (range from 33 and 64), Nepalese-British had an average of 55.6 (range from 34 and 67), the Chinese-British group had an average of 54.4 (range from 40 and 65) and the Native-Chinese had an average of 51.1 (range from 33 and 62). A one-way between-participants ANOVA displayed no significant differences between the groups in Individualism scores, $F(3,79) = .402$, $p = .752$, and no significant differences in Collectivism scores, $F(3,79) = 1.173$, $p = .326$.

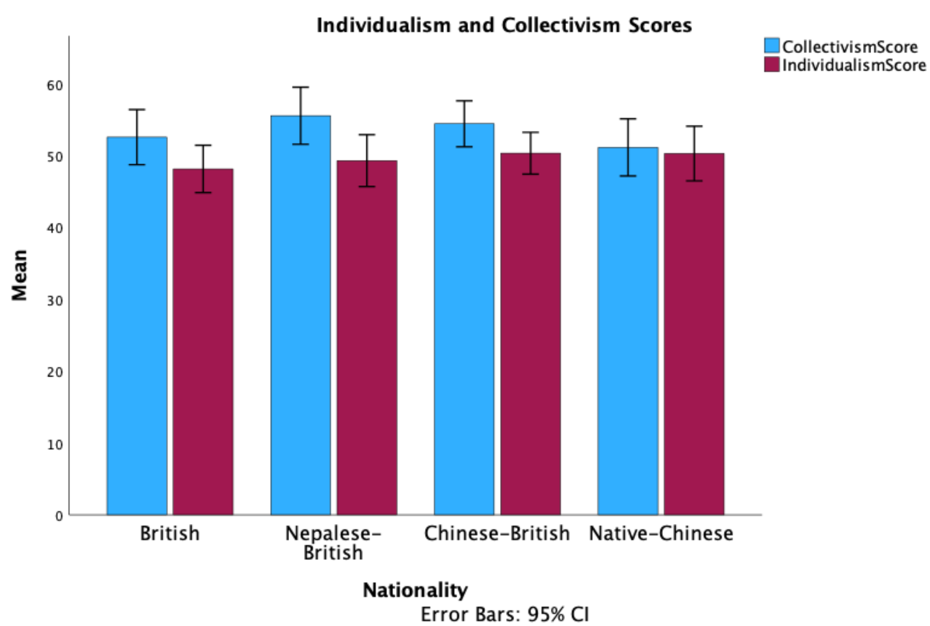


Figure 11. A bar graph displaying the similarity in Individualism and Collectivism Scores of the Nationality groups.

3.4 Language History Questionnaire (LHQ)

Reading and writing self-report scores of participants' second language (possible range 0 - 7) were classified into "high" (scores between 4-7) and "low" (scores 1-3). See Table 3 for the L2 language, reading, and writing scores for each group.

Group	L2 Language	Reading M(SD)	Writing M(SD)
British (N=12)	French/Spanish/Welsh	3.42 (1.78)	2.38 (1.85)
Nepalese-British (N=19)	Nepalese	2.68 (1.73)	2.32 (1.45)
Chinese-British (N= 20)	Chinese	4.05 (1.47)	3.3 (1.03)
Native-Chinese (N=21)	English	5.52 (1.17)	4.8 (1.12)

Table 3. The means and standard deviations of reading and writing scores of the L2 across four participant groups.

A one-way ANOVA was performed to compare the L2 reading skills (dependent variable) of four nationalities with different L2: European, Nepalese, Chinese, and English (independent variables). A one-way ANOVA revealed that there was a statistically significant difference in the reading skills of L2 between at least two groups ($F(3, 79) = [15.99]$, $p<0.001$). Tukey's HSD Test for multiple comparisons found that the mean L2 reading score was significantly different between the British group (European L2) and Chinese-British group (Chinese L2) ($p = 0.011$, 95% C.I. = [-3.12, -0.30]). The mean score was also significantly different between the British group (European L2) and the Native-Chinese group (English L2)($p<.001$, 95% C.I. = [-4.79, -1.97]). In addition, the mean score was significantly different between Nepalese-British (Nepalese L2) and Native-Chinese group (English L2)($p<.001$, 95% C.I. = [-4.40, -1.55]). Also, the mean score was significantly different between Chinese-British (Chinese L2) and the Native-Chinese group (English L2)($p=.014$, 95% C.I. = [-3.08, -0.26]). However, there was no statistically significant difference in mean L2 reading scores between the British group (European L2) and Nepalese-British (Nepalese L2) ($p=0.88$), as well as between the Nepalese-British (Nepalese L2) and Chinese-British (Chinese L2) group ($p=0.85$).

Another one-way ANOVA was performed to compare the L2 writing skills of the four groups. A one-way ANOVA revealed that there was a statistically significant difference in the writing skills of L2 between the groups ($F(3, 79) = [17.00]$, $p<0.001$). Tukey's HSD Test for multiple comparisons found that the mean L2 reading score was significantly different between the British group (European L2) and Chinese-British group (Chinese L2) ($p = 0.019$, 95% C.I. = [-2.59, -0.17]). The mean score was also significantly different between the British group (European L2) and the Native-Chinese group (English L2)($p<.001$, 95% C.I. = [-4.26, -1.84]). In addition, the mean score was significantly different between Nepalese-British (Nepalese L2) and Native-Chinese group (English L2)($p<.001$, 95% C.I. = [-3.84, -1.38]). Also, the mean score was significantly different between Chinese-British (Chinese L2) and the Native-Chinese group (English L2)($p=.003$, 95% C.I. = [-2.88, -0.45]). However, there was no statistically significant difference in mean L2 reading scores between the British group (European L2) and Nepalese-British (Nepalese L2) ($p=0.79$), as well as between the Nepalese-British (Nepalese L2) and Chinese-British (Chinese L2) group ($p=0.19$).

Overall, the British group differed significantly from Chinese-British and Native-Chinese, but not Nepalese-British. The Nepalese-British group was only significantly different from the Native-Chinese group. Chinese-British and Native-Chinese groups were significantly different.

3.5 Data analysis: Linear mixed effect models

As mentioned earlier, we used the LMM method of analysis due to the correlation between our three tasks. A Pearson correlational analysis was used to examine the relationship between the three tasks in order to test for correlations in RT: Navon, Visual Discrimination, and Visual Search Task. See **Table 4** for all correlations.

Tasks	Navon (Local)	Navon (Global)	VDT	Visual Search
Navon (Local)				
Navon (Global)	.72**			
VDT	.20	.18		
Visual Search	.28*	.28**	.34**	

* Correlation is significant at the 0.05 level (2-tailed).
** Correlation is significant at the 0.01 level (2-tailed). N = 83

Table 4. Correlation matrix displaying the correlations between the Navon (local and global feature), Visual Discrimination, and Visual Search Task.

The Visual Search task was positively correlated to all tasks except the Visual Discrimination task. There was a weak positive correlation between Search and Global (Navon), r (81) = .28, p = .01. There was a weak positive correlation between Search and Local (Navon), r (81) = .27, p = .01. Moreover, there were two weak negative correlations between the Corsi Block task and the Search and Local (Navon) task. Local (Navon) and Corsi-Block were found to be weakly negatively correlated, r (81) = -.24, p = .03. Search and Corsi-Block were found to be weakly negatively correlated, r (81) = -.28, p = .01. Also, the Global (Navon) and Local (Navon) were highly positively correlated, r (81) = .72, p<0.001.

Following this, LMM was the chosen method of analysis. The data from each assessment was analysed using linear mixed-effects modelling due to the benefits of mixed-effects models with crossed random effects over traditional, by participant, by item ANOVAs (Baayen et al., 2008). The model primarily tested for the effects of the different groups on RT. In order to explain by-participant and by-item variation and negate the effects of potential covariates including order effect, learning, and fatigue, participants and items were treated as random effects.

Firstly, we fitted separate models for each task by building random effects structures following a maximal approach. This means that random effects were included as random intercepts as well as correlated random slopes (random variations) as long as they converged and were justified by the data (Barr et al., 2013). The model structure was simplified in a step-by-step procedure comparing a model with a given variable against a model without a given variable, and models were deemed superior/more parsimonious based on the Akaike Information Criterion (AIC; lower AIC values indicate better fitting models)(Vrieze, 2012). In each individual assessment for each task, we tested all variables within each task and only the variables that improved the model were kept in the final analysis.

3.5.1 Reaction Time (ms) models

For each RT model, the following predictor variables were used: independent variables included all four nationalities (British, Nepalese-British, Chinese-British, Native-Chinese), L1 (1st language), Reading Chinese, Reading English, Reading Other, Writing Chinese, Writing English and Writing Other and the dependent variable was RT in milliseconds. Again, using the step-by-step procedure, the number of variables was reduced due to their weak contribution to the model and kept only if they improved the model. The separate mixed effect models displayed significant predictors in only two tasks: Visual Search and Local (Navon). The Navon task measured both Local and Global features, we only found significant differences in the Local **feature** therefore it is further investigated. All other models were not predicted by the variables used (significance values $p>.05$), and therefore are not discussed further here.

The final Local (Navon) mixed-effects model included the independent variables Nationality, Reading Chinese, Reading Other, and Reading English scores, and the dependent variable was RT in milliseconds. The only significant predictor variable was Nationality ($\beta = -.52$, $p = .01$). The model specification was as follows: LocalZSep ~ Nationality + ReadingChinese + ReadingOther + (1 | Subject) + (1 | LocalItem). See Table 5 for the remaining variables and the insignificant contribution of each variable. The British participants had an average reaction time of 868.2ms, Nepalese-British had an average of 834.9ms, Chinese-British had an average of 804.2ms, and Native-Chinese had an average of 873.8ms (see Figure 12). T-tests were performed to determine which groups (British, Nepalese-British, Chinese-British, and Native-Chinese) were statistically different from each other. But when carrying out the T-tests, there were no significant differences between the four groups for the local feature of the Navon task.

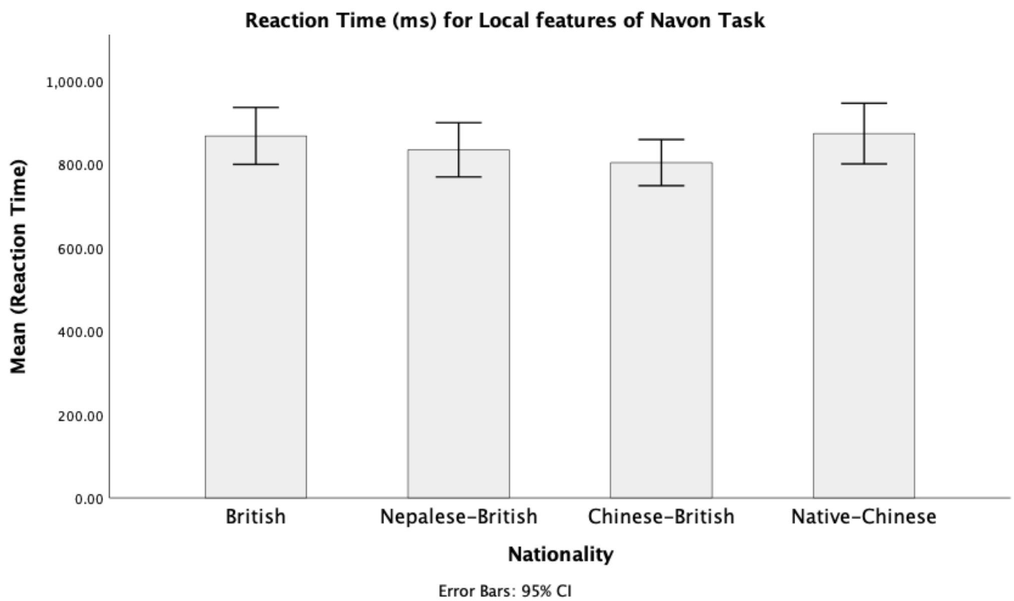


Figure 12. A bar graph to display the mean reaction time (ms) for Navon (local feature) task.

Fixed effects	Estimate (Odds)	Standard error	*z*-value	*p*-value
(intercept)	0.03	0.11	0.27	0.79
Nationality Native-Chinese	-0.59	0.32	-1.83	0.07
Nationality Chinese-British	-0.53	0.19	-2.64	0.01*
Nationality Nepalese-British	-0.09	0.10	-0.96	0.34
Reading Chinese	0.07	0.04	1.63	0.11
Reading Other	-0.04	0.03	-1.67	0.09

* Correlation is significant at the 0.05 level (2-tailed).
** Correlation is significant at the 0.01 level (2-tailed). N = 83

Table 5. The Fixed effect parameter estimates of the final model for reaction time (ms) in the Navon Task (Local feature).

The final model for Visual Search included the independent variables Nationality, Reading Chinese, Writing Chinese, Reading English, Writing English, Reading Other, and Writing Other scores. Reading and Writing Other represented the scores for including European languages French, Spanish and Welsh, and Nepalese. See figure 13 for the average reaction time for each Nationality group.

In this model, Nationality was a significant predictor ($\beta = -.59$, $p<.001$). The model specification was as follows: SearchZSep ~ Nationality + ReadingChinese + ReadingOther + WritingOther + (1|Subject) + (1|SearchItem). See Table 6 for the insignificant contribution of each other variable in the final model. T-tests were performed to determine which of the groups (British, Nepalese-British, Chinese-British, and Native-Chinese) differed from each other. The Chinese-British ($M = 824.5$, $SD = 120.8$) compared to the British group ($M = 983.8$, $SD = 132.4$) demonstrated significantly faster reaction times, $t(40) = 4.07$, $p < .001$. Compared to Nepalese-British ($M = 900.9$, $SD = 118.6$), the Chinese-British displayed significantly faster reaction times, $t(40) = 2.04$, $p = .048$. When Chinese-British were compared to the Native-Chinese ($M = 982.9$, $SD = 123.8$), they were significantly faster, $t(40) = -4.19$, $p < .001$. To add, we also found Nepalese-British compared to British displayed significantly faster reaction times, $t(40) = 2.11$, $p = .042$. Also, Nepalese-British compared to Native-Chinese displayed significantly faster reaction times, $t(40) = -2.16$, $p = .037$. However, we found no significant differences between the British and Native-Chinese.

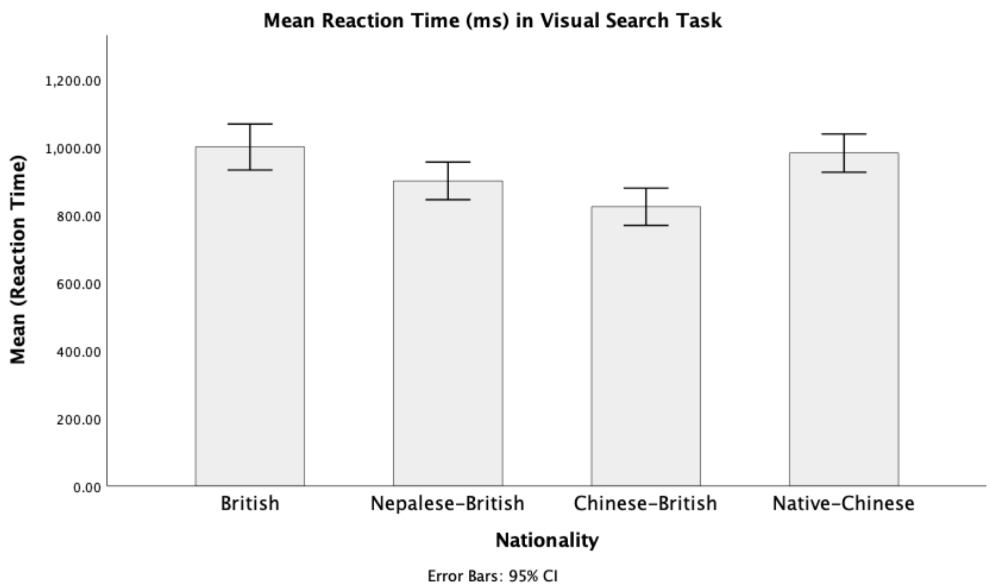


Figure 13. A bar graph to display the reaction times (ms) in the Visual Search Task.

Fixed effects	Estimate (Odds)	Standard error	*z*-value	*p*-value
(intercept)	.001	0.09	0.01	0.99
Nationality Native-Chinese	-0.44	0.25	-1.74	0.08
Nationality Chinese-British	-0.59	0.16	-3.77	<.001***
Nationality Nepalese-British	-0.17	0.08	-2.18	0.03*
Reading Chinese	0.05	0.03	1.72	0.08
Reading Other	0.15	0.06	2.46	0.09
Writing Other	-0.20	0.07	-2.93	0.12

* Correlation is significant at the 0.05 level (2-tailed).
** Correlation is significant at the 0.01 level (2-tailed). N = 83

Table 6. The Fixed effect parameter estimates for the final model for reaction time (ms) in the Visual Search Task.

3.5.2 Response accuracy (%) models

The same process of mixed-effects modeling was implemented for accuracy. For each accuracy model, the following predictor variables were used: independent variables included all four nationalities (British, Nepalese-British, Chinese-British, Native- Chinese), L1 (1st language), Reading Chinese, Reading English, Reading Other, Writing Chinese, Writing English and Writing Other and the dependent variable was percentage correct (%). Using the step-by-step procedure, the number of variables was reduced due to their weak contribution to the model. For our accuracy analysis, only the Visual Discrimination Task had significant predictor variables that accounted for some of the variances in accuracy. All other models were not improved by the variables used and therefore are not discussed further here.

In the final Visual Discrimination mixed-effects model, the model specification was as follows: lmer(VDTcorr ~ ReadingChinese + WritingChinese + (1|Subject)+ (1|VDTitem). Two significant predictors of accuracy were found: Reading Chinese ($\beta = .06$, $p =.0054$) and Writing Chinese ($\beta = -0.06$, $p =.0075$)(See Table 7). T-tests were performed to determine whether reading and writing Chinese improved or worsened accuracy levels. However, we found no significant differences between Chinese readers and non-Chinese readers. See Figure 14, displaying the bar graph for the average accuracy scores across the four groups. The groups had the following average accuracy scores: the British Group had an average of 75.4% (SD = 10.9), Nepalese-British also had an average of 75.4% (SD = 10.4), the Chinese-British had an average of 81.3% (SD = 10.6) and lastly, the Native-Chinese had an average of 75.9% (SD = 10.4).

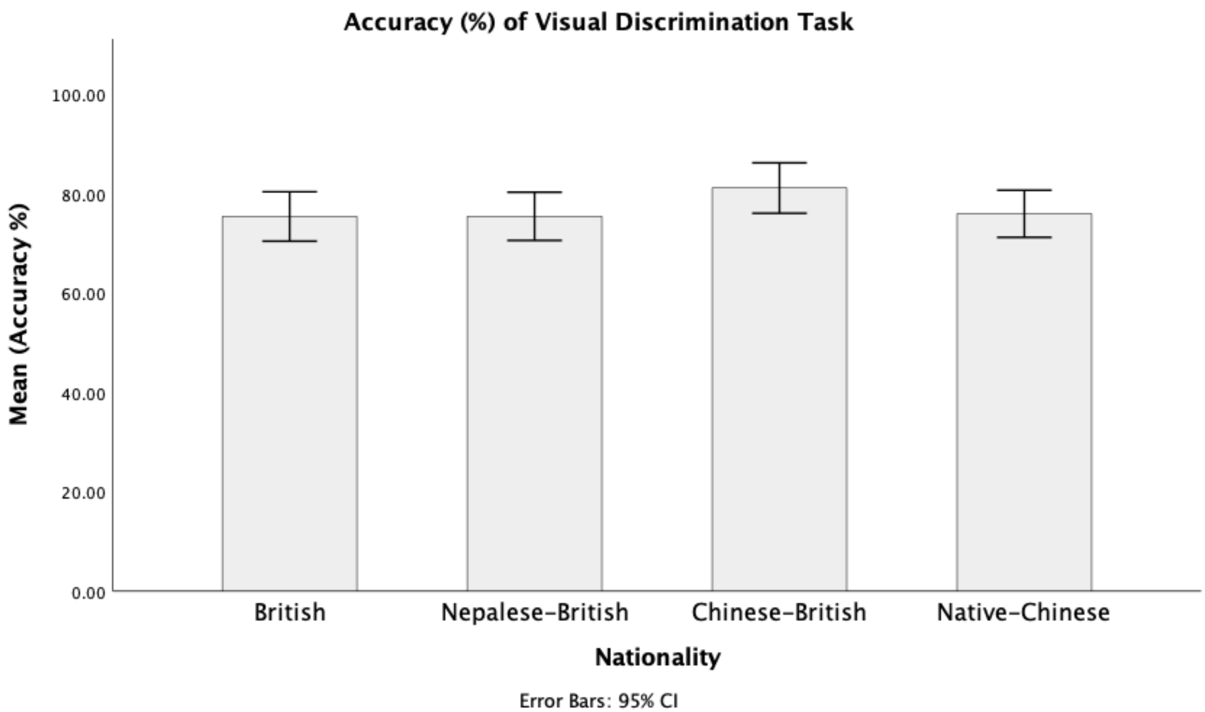


Figure 14. A bar graph to display the accuracy scores (%) in the Visual Discrimination Task.

Fixed effects	Estimate (Odds)	Standard error	*z*-value	*p*-value
(intercept)	.76	.03	22.1	.00***
Reading Chinese	.06	.02	2.85	.005**
Writing Chinese	-.06	.02	-2.74	.007**

* Correlation is significant at the 0.05 level (2-tailed).
** Correlation is significant at the 0.01 level (2-tailed).
*** Correlation is significant at the 0.00 level (2-tailed). N = 83

Table 7. The Fixed effect parameter estimates for the final model for accuracy data in the Visual Discrimination Task.

DISCUSSION

The ultimate goal of this research was to expand our understanding of how the experience of reading visually complex scripts affects attentional processes and visual discrimination and search skills. The following hypotheses were tested:

Hypothesis 1: Chinese readers (British and Native) will display a global bias compared to non-Chinese readers (British and Nepalese).

Hypothesis 2: Chinese readers (British and Native) are faster and more accurate at discriminating between similar visual patterns than non-Chinese readers (British and Nepalese).

Hypotheses 3: Chinese readers (British and Native) are faster and more accurate at searching for a target amongst distractors than non-Chinese readers (British and Nepalese).

Our results provide partial support for these hypotheses. Regardless of cultural orientation, Chinese-British was fastest in the Visual Search Task and reading and writing Chinese resulted in more accurate performance in the Visual Discrimination Task. Even though Nationality was a significant factor in the local element of the Navon Task, no significant differences were found between the different groups. We discuss our findings, the limitations of the study, the implications of the project, and our concluding remarks.

4.1 Navon Task - Hypothesis 1

The Navon task measured two elements of attention: global and local. Hypothesis 1 predicted that Chinese readers would be faster and more accurate in identifying the letter in the global features because many characters have visual similarities, so it is important to process the whole character to determine its meaning and pronunciation (Luo et al., 2013). Interestingly, we found Nationality to be a significant predictor in the Local element. However, the additional analysis could not locate the differences between the four nationalities (British, Nepalese-British, Chinese-British, and Native-Chinese). Past research indicates cultural experiences determine our attentional bias: with displays viewed either globally or locally (Nisbett et al., 2001). These studies attribute differences to cultural orientation where Easterners have a global bias and Westerners have a local bias (Masuda & Nisbett, 2006). However, there was no statistical difference in individualism and collectivism scores between the four groups, yet we still found nationality to be a significant predictor of local processing. This challenges research by Nisbett & Miyamoto (2005) and Masuda & Nisbett (2006) because their explanations for attentional differences are solely cultural. Although we could not identify which nationality was predicting the local bias, our finding creates a path for further investigation into the involvement of script in developing specific attentional biases.

Furthermore, we first looked at research on the Himba people who displayed extreme local attention regardless of having no written language (Davidoff, Robertson & Shapiro, 2002). We speculated that our global attention is developed according to the visual demands of the script we learn and that our human tendency before learning to read is local processing. From our findings, nationality seems to be a factor that impacts local processing, but there is no clear-cut distinction between visual script complexity and attentional processes. However, this finding should not be overlooked and raises a few interesting questions.

One possibility could be because of low statistical power as the British group only had 12 participants, Nepalese-British had 19, Chinese-British had 20 and Native-Chinese had 21. Although at first this may be overlooked over methodological issues, however, sample size concern is valid and has major significance (Faber & Fonseca, 2014). Sample sizes can be either too big or too small and both have limitations. A sample size that is too can prevent findings from being extrapolated or differences from being detected, whereas a sample size too large may magnify the detection of statistical differences that are not clinically applicable (Altman, 1990). From this understanding, we propose our sample size was too small to detect differences between the groups. Going forward, we suggest using more participants and having the same number of participants in each group.

4.2 Visual Discrimination - Hypothesis 2

From our understanding of perceptual learning (Fahle & Poggio, 2004), we hypothesised that Chinese readers' who can discriminate between similar-looking characters (such as 土 and 士) would be faster and more accurate in discriminating between similar-looking shapes than non-Chinese readers. This hypothesis was further motivated by the fact that there are significantly higher correlations between English words than Chinese characters (Hsiao & Lam, 2013). We did find reading and writing Chinese to be significant predictors in the accuracy scores of the Visual Discrimination Task. However, the further analysis did not identify any significant differences. Furthermore, no significant predictors were found in the reaction time models for the VDT task. Again, this could be due to our small sample size which was insufficient to detect statistical differences between the groups. In spite of that, we discuss other possible explanations for these findings below.

An alternative explanation for our results could be the use of geometric shapes in our VDT task. Some researchers have proposed that character and geometric shape processing are two distinct visual processes (Luo et al., 2013). The authors suggest that identifying general shapes could be developed through observing geometric patterns in everyday surroundings rather than literacy practices. If we take a detailed look at our results, we only found significant results in tasks in which stimuli used alphabetic letters, such as the Visual Search Task (finding the T target) and the Navon (Local) Task (finding the H and O target letters). Since then we have become skeptical of the nature of our stimuli, although we still strongly adopt the perceptual learning perspective, we question the generalisability of the skill to other areas.

Moreover, we started making connections between studies that were previously unrecognised; we now realise that Duñabeitia, Orihuela, & Carreiras (2014) used letter strings in the perceptual matching task. Therefore, when the position of letters was adjusted, literates were quick to identify them as they have experience distinguishing between letters, unlike the illiterates. Similarly, Hatta (1977) presented Kanji characters to detect activation in the right visual field of the left hemisphere. So although reading Chinese involves a higher level of visual discrimination skill, it could be that the skill is not generalised to other stimuli (geometric shapes). In future experiments, a task that uses more complex stimuli to challenge visual skills, such as pseudo-character stimuli, would be a more valid measure directly associated with reading a complex script.

To expand further, we previously understood that readers of alphabetic languages display left-hemispheric lateralisation (McCandliss, Cohen & Dehaene, 2003), compared to Chinese readers who display right-hemisphere lateralisation (Tzeng et al., 1970). Although we acknowledge that the right occipital cortex identifies visual and spatial recognition of objects, this may retain within character processing. We initially predicted that these skills are generalised to other tasks using similar visual skills, but now we consider that the skills are advanced characteristically. For example, referring back to professional keyboard players, those who started at an early age developed symmetrical primary motor cortices (Amunts et al., 1977). However, if these professional keyboard players attempt to play another instrument requiring similar motor movements, they will not be 'professionals' at the new instrument. Although some similar motor movements may be involved, it is an entirely different context and stimuli the individual has little experience with. Even though pictographs form Chinese characters that activate areas in the brain involved in visual and spatial recognition (Tan & Siok, 2006), we could also argue (although it is a strong proposition) that neural adaptations may not be generalised for other stimuli such as geometric shapes.

4.3 Visual Search - Hypothesis 3

We predicted Chinese readers to perform better in the Visual Search Task because identifying Chinese characters require distinguishing between several characters that share visual resemblances in stroke combinations (Luo et al., 2013). To some degree, in line with hypothesis 3, we found people's Nationality and reading/writing in European or Nepalese scores to be significant predictors in the Visual Search Task. Amongst the three-second language groupings (European, Nepalese, and Chinese), we found Chinese readers to perform the fastest. The visual search task involves ignoring similar distractors and identifying the target; it is a fundamental visual skill, especially when reading Chinese. The English and Chinese languages are distinctly different (McBride, 2016). Previous studies have continuously explained differences in visual search through cultural differences (Nisbett & Miyamoto, 2005; Masuda & Nisbett, 2006;

Kuwabara and Smith, 2012), but our findings provide an alternative outlook. The four groups did not significantly differ in their collectivism or individualism scores, meaning there may be an element of reading a visually complex script that drives this visual benefit instead of their cultural orientation. What exactly is driving these differences remains to be clarified. Regardless, our findings still should highlight the gap that previous research has ignored.

To add, even when reading visually simple scripts, we rely on visual features (Gibson, 1971). Ehri's development theory (1991) declared that recognition of words solely depends on the visual elements during the early stages of reading. This can refer to children beginning to read or adults who are not fluent in reading another language. The theory could potentially explain why we found Chinese-British participants to perform the fastest in the Visual Search Task. Since none of the Chinese-British participants was fluent in reading Chinese, they were more inclined to rely on visual features hence why they performed better in the Visual Search Task. Studies mentioned earlier by Geva & Siegel (2000) and Kuwabara and Smith (2012) used children as participants. As these studies investigated children, with regard to the theory, their reading skills are most likely based on visual features, so differences in such tasks may appear prominent. It would be interesting to test this hypothesis using children because it appears that the impact of reading visually complex languages may only be found at the early stages of reading. It could be that when learning to read a language, we first acknowledge the visual features. Therefore, the stage of reading (whether childhood or adulthood) is an essential factor to consider.

4.4 Culture or script?

We assessed the cultural orientation of our participants to explore its involvement in visual processing, as has been previously claimed (Nisbett & Miyamoto, 2005). We included culturally diverse groups with skills in either simple or complex writing systems; the groups were: Nepalese-British, Chinese-British, Native-Chinese, and British. However, the scale revealed no significant differences between any groups in both their Individualism and Collectivism scores. This is an interesting finding because there was no difference in cultural orientation between the different groups. Still, there was a nationality difference in the Local (Navon) task. We acknowledge that this finding is not sufficient to say visual search differences are driven by the visual complexity of the script, but we highlight an area of research that has long gone unnoticed and is worth investigating.

Furthermore, the Culture Orientation scale may not have shown differences in our population group because it is not sensitive enough to measure the complexity of the cultural orientation of our participant groups. As mentioned before, there is much debate around the cultural identity of younger generations of ethnic minority groups (Finney and Simpson, 2009) and nowadays culture is more malleable (Anthias, 2001). The scores of older generation individuals on the Culture Orientation Scales may appear more pronounced than people of younger generations because they are more multicultural and thus adopt elements of different cultures in their everyday lives. Nowadays, there are more bilingual/multilingual than monolinguals in the world (Marian & Shook, 2012). Even if we experimented in China or Nepal, it would be tough to find pure monolingual individuals since most start learning English or other languages from a young age. Hence, we believe that our sample is more representative of the real world. The British- Chinese and Nepalese-British communities are far more complex, and many do not form collectivist cultures like those in their countries of origin. As our participant samples were exposed to both Collectivist and Individualist cultures, a more sensitive questionnaire would better grasp the cultural orientation of multicultural individuals. In future research, more sensitive measurements of cultural orientation may be considered and used as a tool to recruit participants instead of measuring their orientation after being recruited.

4.5 Unexpected findings

Although our findings were not what we had hoped, there were significant and somewhat consistent with our predictions, but also a few unexpected findings were discovered. In the Language History Questionnaire, we recorded the reading and writing scores of participants' L2 languages (European, Nepalese, Chinese, and English). The one-way ANOVA revealed a significant difference in the reading skills of L2 between at least two groups. Post hoc tests uncovered these differences and found the British group differed significantly from Chinese-British and Native-Chinese, but not Nepalese-British. The Nepalese-British group was only significantly different from the Native-Chinese group. Chinese-British and Native-Chinese groups were significantly different.

This finding led us to question, what does this signify? What implications does it have? Does reading a complex script enable easier second language acquisition? Looking back at Table 2, the Native-Chinese group had the highest reading and writing scores for their L2 (English) out of all four groups. This is interesting and could be connected to our hypotheses, if we look back at the Script Relativity Hypothesis, it declared prolonged reading of a certain script has the potential to influence thought processes and cognitions (Pae, 2022). Accordingly, we put forward, since Native-Chinese groups are fluent in reading Chinese (a visually complex script), it may be easier for them to learn visually simple scripts such as English. We are conscious of this strong speculation that requires extensive research. However, the majority of research on the Script Relativity Hypothesis focuses on other areas of scripts such as the spatial layout (Winskel, 2022). To add, we need to examine the participants' exposure to multiple languages and scripts.

Not only that, but external factors such as education practices and methods (Nag, Vagh, Dulay & Snowling, 2019), and cultural differences cannot be accurately extracted from cross-cultural comparisons (Chang, 2015). Therefore, our findings from behaviouaral tasks must be accepted with caution.

4.6 Clinical implications

This research project aimed to investigate the impact of reading visually complex scripts on attentional processes and visual discrimination and search skills. As mentioned earlier, the author of this project is Nepalese-British and grew up in a bilingual household. The United Kingdom is multi-cultural and attentional and visual skill differences are essential to understand as they have implications for reading models for second language learners and education policies for immigrants/refugees. Bearing in mind, the digital revolution has increased globalisation rapidly over the past decade and now being able to speak more than one language is becoming a necessity in workplaces and in education.

4.7 Methodological issues - COVID-19

The COVID lockdown required everyone to stay at home, the tasks were carried out online, and the environmental setting could not be controlled or checked by the researchers in any way. Therefore, we could not guarantee that participants completed the tasks in a non-distracting environment. The size of the screen or the distance from the screen also could not be controlled. If the experiment were completed in a lab, we would measure the distance from the screen and have participants place their heads on a chin rest. Sitting at a greater distance will make it easier to spot the differences because getting broader attention, especially in the Visual Discrimination or Visual Search Task. Not only that, but the computer in the lab would have been the same for everyone, considering everyone used a different-sized computer screen; those with a larger computer screen could perform better as the differences would appear more transparent than those with a smaller computer screen. We aim to increase the internal validity of the findings by swapping the experimental setting to the lab, instead of executing the study online. We can only assume these factors contributed to the variability in our results as we cannot confidently say that these extraneous variables were effectively controlled. Thus, we propose these methodological issues contributing to not finding significant differences in the further analysis of the Local (Navon) task.

4.8 Conclusion

Overall, this thesis has presented some evidence, although not strong, supporting two of our hypotheses that readers of visually complex scripts create an advantage in visual discrimination/search tasks. This study provides an interesting perspective to understand the differences in visual skills between visually complex and simple script readers. The study is novel in using second-generation Nepalese and Chinese participants to cancel out cultural effects. Instead of solely focusing on the cultural effect, we have emphasized further how important it is to consider the visual complexity of scripts since it is one of the main differences (Chang, 2015). Due to this, we strongly encourage future research to select more challenging tasks, implement pseudo characters or letters, and use a well-rounded measure for culture orientation. The continuing investigation into the effects of script on visual skills is a promising area that could help develop reading models, education policies, and understanding for people worldwide who want to learn visually complex languages. We cannot disregard the importance of the visual complexity of scripts. The question of whether attentional and visual skill differences result from culture, or the visual complexity of script remains. Thus, we hope that further research will further investigate this topic better to understand the remarkable complexity of the human language.

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APPENDIX A - Consent Form

Participant ID:

This form is to be completed independently by the participant after reading the Information Sheet and having listened to an explanation about the research.

The study has been approved by the UOB Research Ethics Committee

Supervisor of project: Dr Robin Thompson: [redacted]

Participant's Statement

I agree to the following statements:

- I have read the information sheet and the project has been explained to be orally.
- I have had the opportunity to ask questions and discuss the study.
- I have received satisfactory answers to all my questions or have been advised of an individual to contact for answers to pertinent questions about the research and my rights as a participant and whom to contact in the event of a research related injury.
- I understand that I am free to withdraw from the study without penalty if I so wish.
- I consent to the processing of my personal information for the purposes of this study only and understand that it will not be used for any other purpose.
- I understand that such information will be treated as strictly confidential and handled in accordance with the provisions of the Data Protection Act 1998.

Signature of participant:

Name of participant (IN BLOCK CAPITALS):

Date:

Investigator's statement

I confirm that I have carefully explained the purpose of the study to the participant and outlined any reasonably foreseeable risks or benefits (where applicable).

Signature of the researcher:

Date:

APPENDIX B - Information Sheet

This study explores the effects of reading visually complex vs visually simple writing scripts (Chinese vs English) on basic visual skills.

The experiment is divided into eight parts which are explained below:

1. **Language History Questionnaire (10 minutes)**
   This is just a simple questionnaire asking you about your language history. For example, the different languages you speak, how often you speak them and when you started learning them.

2. **Culture Orientation Questionnaire (5 minutes)**
   This is a quick survey measuring your cultural orientation. For example, how much you identify with collective or individualistic cultures. You will read 16 statements and rate how much you agree with each one.

3. **Matrices Task (10 minutes)**
   You will see a set of images with one missing. You will be asked to decide which image (out of 4 at the bottom of the page) best fits in with this set.

4. **Visual Discrimination Task (10-15 minutes)**
   This is a matching task where you will be shown a target image and four other images. Out of the four images, you need to identify the image identical to the target image.

5. **Corsi-Block Tapping Task (<5 minutes)**
   You will be shown 9 square blocks that change colour one by one in a given sequence. You then have to copy the pattern by clicking on the blocks in the same order of the sequence you saw.

6. **Visual Search Task (<5 minutes)**
   For this task, you are visually searching for a target on the screen. All you have to do is respond whenever you see the target.

7. **Mental Rotation Task (<5 minutes)**
   This task requires your imagination. You will see a single target shape with two more shapes below it. You must pick which of the two shapes matches the one at the top. the match will be identical to the target but rotated at an angle either clockwise or anticlockwise. You have to mentally rotate the target shape and click the matching rotated image.

8. **Navon Figure Task (<5 minutes)**
   Here you will see a big sized letter made up of smaller sized letters. All you have to do is respond when you see a target letter (an 'H' or 'O').

ORTHOGRAPHY VISUAL COMPLEXITY AND VISUAL SKILLS

All these tasks are simple visual tasks which should cause no discomfort. In between tasks you can take breaks as needed. Further, if you decide that you want to withdraw from the experiment, you may do so at any point.

The session is expected to last approximately 1 hour. As a token of gratitude for your time, you can consult the researcher to discuss a reward. To provide consent to participate, please sign below:

-

Signature of participant:

Name of participant (IN BLOCK CAPITALS):

Date:

As the researcher, I have explained the study to the above participant and he/she has agreed to take part.

Signature of the researcher:

Date:

If you have any further questions regarding the specifics of the study, then you may contact:

Awisha Magar [redacted]

OR

Dr Robin Thompson [redacted] (SUPERVISOR)

APPENDIX C - Language History Questionnaire (LHQ)

1. List all the languages you know or have studied. List in order from your strongest (most proficient) language to your weakest language (least proficient). List up to 4 different languages including English.

   Language 1:
   Language 2:
   Language 3:
   Language 4:

2. At what age did you start using each language in terms of listening?

   Language 1:
   Language 2:
   Language 3:
   Language 4:

3. At what age did you start using each language in terms of speaking?

   Language 1:
   Language 2:
   Language 3:
   Language 4:

4. At what age did you start using each language in terms of reading?

   Language 1:
   Language 2:
   Language 3:
   Language 4:

5. At what age did you start using each language in terms of writing?

   Language 1:
   Language 2:
   Language 3:
   Language 4:

6. What is the total number of years you have spent using each language?

Language 1:
Language 2:
Language 3:
Language 4:

7. If you have lived or travelled in countries other than your country of residence/origin for three or more months, please indicate the name of the country, your length of stay, and the language you used when you were in each country.

8. Please indicate the frequency of your use of the language per country. Please tick the appropriate box.

	Never	Rarely	Sometimes	Regularly	Often	Usually	Always
Language 1							
Language 2							
Language 3							
Language 4							

9. How many years have you spent learning each language in a formal setting?

Language 1:
Language 2:
Language 3:
Language 4:

10. On a scale of 1 to 10, please select how much the following factors contributed to you learning each language. Please tick the appropriate box.

	None	1	2	3	4	5	6	7	8	9	10
Language 1											
Language 2											

Language 3											
Language 4											

a. Interacting with family.

	None	1	2	3	4	5	6	7	8	9	10
Language 1											
Language 2											
Language 3											
Language 4											

b. Reading

	None	1	2	3	4	5	6	7	8	9	10
Language 1											
Language 2											
Language 3											
Language 4											

c. Language tapes/self-instruction

	None	1	2	3	4	5	6	7	8	9	10
Language 1											
Language 2											

Language 3											
Language 4											

d. Watching TV

	None	1	2	3	4	5	6	7	8	9	10
Language 1											
Language 2											
Language 3											
Language 4											

e. Listening to the radio

	None	1	2	3	4	5	6	7	8	9	10
Language 1											
Language 2											
Language 3											
Language 4											

11. Please list the number of years and months you spent in a school and/or working environment where each language was spoken.

Language 1:
Language 2:
Language 3:
Language 4:

12. Rate your current ability in each of the languages you have studied or learned in terms of speaking, reading, writing and listening. Please tick the appropriate box.

a. Speaking

	Very Poor	Poor	Limited	Functional	Good	Very good	Like a native	N/A
Language 1								
Language 2								
Language 3								
Language 4								

b. Reading

	Very Poor	Poor	Limited	Functional	Good	Very good	Like a native	N/A
Language 1								
Language 2								
Language 3								
Language 4								

c. Writing

	Very Poor	Poor	Limited	Functional	Good	Very good	Like a native	N/A

Language 1								
Language 2								
Language 3								
Language 4								

d. Understanding

	Very Poor	Poor	Limited	Functional	Good	Very good	Like a native	N/A
Language 1								
Language 2								
Language 3								
Language 4								

13. Estimate, in terms of percentages, how often you use your native language and other languages per day (in all daily activities combined). Please tick the appropriate box.

	<25%	25%	50%	75%	100%	N/A
Language 1						
Language 2						
Language 3						
Language 4						

ORTHOGRAPHY VISUAL COMPLEXITY AND VISUAL SKILLS

14. Estimate, in terms of hours per day, that you spend engaged in listening to or watching podcasts/radio/tv for each of the languages you have studied or learned. Please tick the appropriate box.

	Never	Under 2 hrs	2-4 hrs	4-6 hrs	6-8 hrs	8-10 hrs	10+ hrs	N/A
Language 1								
Language 2								
Language 3								
Language 4								

15. Estimate, in terms of hours per day, that you spend engaged in reading for fun for each of the languages you have studied or learned.

	Never	Under 2 hrs	2-4 hrs	4-6 hrs	6-8 hrs	8-10 hrs	10+ hrs	N/A
Language 1								
Language 2								
Language 3								
Language 4								

16. Estimate, in terms of hours per day, that you spend engaged in reading for work for each of the languages you have studied or learned.

	Never	Under 2 hrs	2-4 hrs	4-6 hrs	6-8 hrs	8-10 hrs	10+ hrs	N/A
Language 1								
Language 2								
Language 3								
Language 4								

17. Estimate, in terms of hours per day, that you spend engaged in reading on the internet for each of the languages you have studied or learned.

ORTHOGRAPHY VISUAL COMPLEXITY AND VISUAL SKILLS

	Never	Under 2 hrs	2-4 hrs	4-6 hrs	6-8 hrs	8-10 hrs	10+ hrs	N/A
Language 1								
Language 2								
Language 3								
Language 4								

18. Estimate, in terms of hours per day, that you spend engaged in writing/texting for each of the languages you have studied or learned.

	Never	Under 2 hrs	2-4 hrs	4-6 hrs	6-8 hrs	8-10 hrs	10+ hrs	N/A
Language 1								
Language 2								
Language 3								
Language 4								

19. Estimate, in terms of hours per day, that you spend engaged in writing articles/papers for each of the languages you have studied or learned.

	Never	Under 2 hrs	2-4 hrs	4-6 hrs	6-8 hrs	8-10 hrs	10+ hrs	N/A
Language 1								
Language 2								
Language 3								
Language 4								

20. Estimate, in terms of hours per day, how often you speak in your native, second, third and fourth languages with your spouse/partner.

	Never	Under 2 hrs	2-4 hrs	4-6 hrs	6-8 hrs	8-10 hrs	10+ hrs	N/A
Language 1								
Language 2								

Language 3								
Language 4								

21. Estimate, in terms of hours per day, how often you speak in your known languages with your friends.

	Never	Under 2 hrs	2-4 hrs	4-6 hrs	6-8 hrs	8-10 hrs	10+ hrs	N/A
Language 1								
Language 2								
Language 3								
Language 4								

22. Estimate, in terms of hours per day, how often you speak in your native, second and third languages with your classmates.

	Never	Under 2 hrs	2-4 hrs	4-6 hrs	6-8 hrs	8-10 hrs	10+ hrs	N/A
Language 1								
Language 2								
Language 3								
Language 4								

23. Estimate, in terms of hours per day, how often you speak in your native, second and third languages with your co-workers.

	Never	Under 2 hrs	2-4 hrs	4-6 hrs	6-8 hrs	8-10 hrs	10+ hrs	N/A
Language 1								
Language 2								
Language 3								
Language 4								

ORTHOGRAPHY VISUAL COMPLEXITY AND VISUAL SKILLS

24. In which languages do you usually count, add, multiply, and do simple arithmetic?

25. In which languages do you usually dream?

26. In which languages do you usually express anger or affection?

27. At home, which languages do you feel you usually do better in when reading?

28. At home, which languages do you feel you usually do better in when writing?

29. At home, which languages do you feel you usually do better in when speaking?

30. At home, which languages do you feel you usually do better in when understanding?

31. At work, which languages do you feel you usually do better in when reading?

32. At work, which languages do you feel you usually do better in when writing?

33. At work, which languages do you feel you usually do better in when speaking?

34. At work, which languages do you feel you usually do better in when understanding?

35. When choosing to read a text available in all your languages, in what percentage of cases would you choose to read it in each of your languages? (Assume the original was written in another unknown language) (Percentages should add up to 100).

	0%	25%	50%	75%	100%	N/A
Language 1						
Language 2						
Language 3						
Language 4						

36. When choosing a language to speak with a person who is equally fluent in all your languages, what percentage of time would you choose to speak each language? (Percentages should add up to 100)

	0%	25%	50%	75%	100%	N/A
Language 1						
Language 2						

Language 3						
Language 4						

37. In your perception, how much of a foreign accent do you have in each language?

Language 1:
Language 2:
Language 3:
Language 4:

38. How frequently do others identify you as a non-native speaker based on your accent in each language?

Language 1:
Language 2:
Language 3:
Language 4:

39. If you have taken a standardized test of proficiency for languages other than your native language (e.g. TOEFL or Test of English as a Foreign Language), please estimate your scores for each. (Write the language, scores and name of test).

40. If there is anything else you feel is interesting, important or unusual about your language background or language use, please comment below.

APPENDIX D - Culture Orientation Questionnaire (COQ)

All items are answered on a 9-point scale, ranging from 1= Never or Definitely NO and 9 = Always or Definitely YES.

1. I'd rather depend on myself than others.

1 2 3 4 5 6 7 8 9

2. Parents and children must stay together as much as possible.

1 2 3 4 5 6 7 8 9

3. It is important that I do my job better than others.

1 2 3 4 5 6 7 8 9

4. If a coworker gets a prize, I would feel proud.

1 2 3 4 5 6 7 8 9

5. I rely on myself most of the time; I rarely rely on others.

1 2 3 4 5 6 7 8 9

6. It is my duty to take care of my family, even when 1 have to sacrifice what I want.

1 2 3 4 5 6 7 8 9

7. Winning is everything.

1 2 3 4 5 6 7 8 9

8. The well-being of my coworkers is important to me.

1 2 3 4 5 6 7 8 9

9. I often do "my own thing."

1 2 3 4 5 6 7 8 9

10. Family members should stick together, no matter what sacrifices are required.

1 2 3 4 5 6 7 8 9

11. Competition is the law of nature.

1 2 3 4 5 6 7 8 9

12. To me, pleasure is spending time with others.

1 2 3 4 5 6 7 8 9

13. My personal identity, independent of others, is very important to me.

1 2 3 4 5 6 7 8 9

14. It is important to me that I respect the decisions made by my groups.

1 2 3 4 5 6 7 8 9

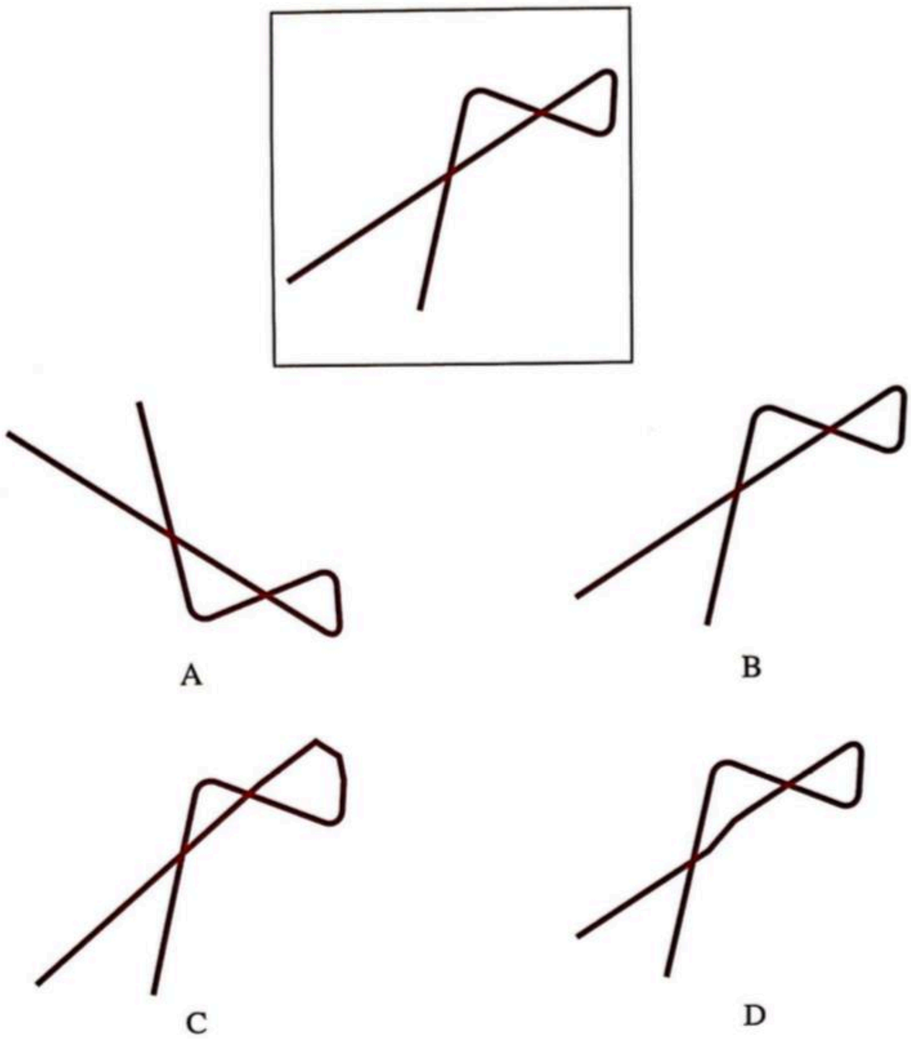
15. When another person does better than I do, I get tense and aroused.

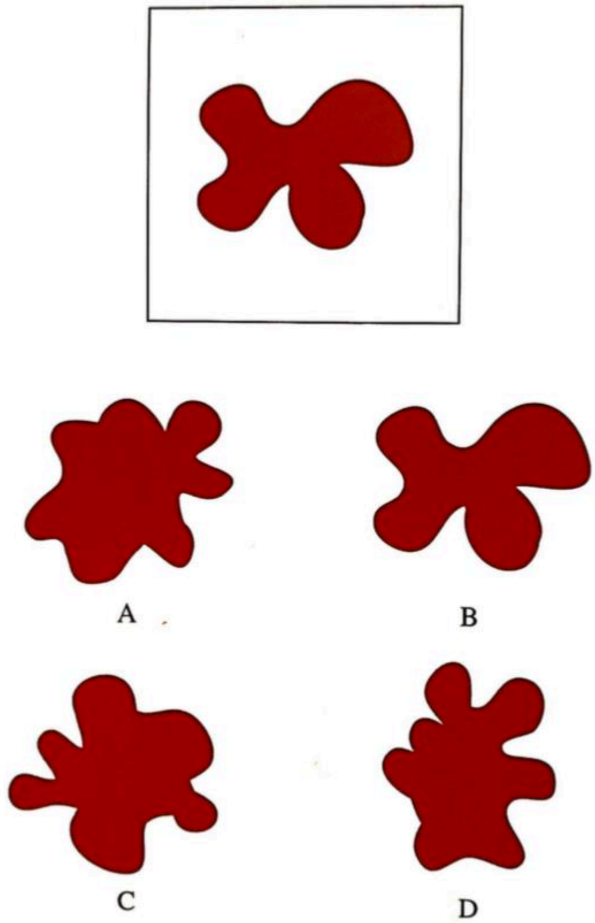
1 2 3 4 5 6 7 8 9

16. I feel good when I cooperate with others.

1 2 3 4 5 6 7 8 9

APPENDIX E - Visual Discrimination Stimulus (Book 1)

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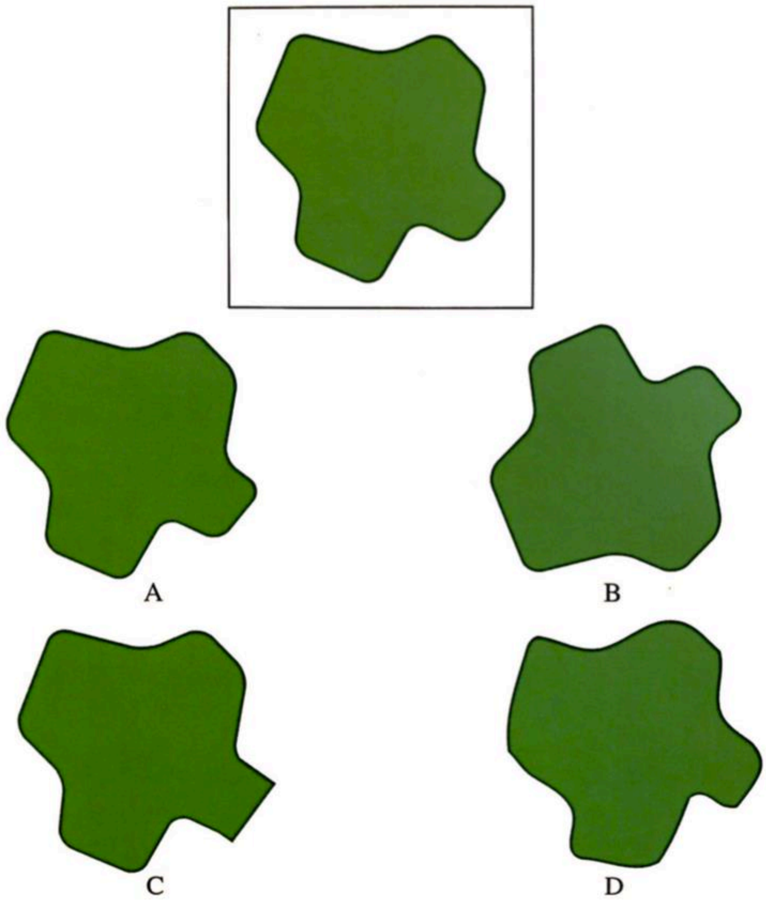
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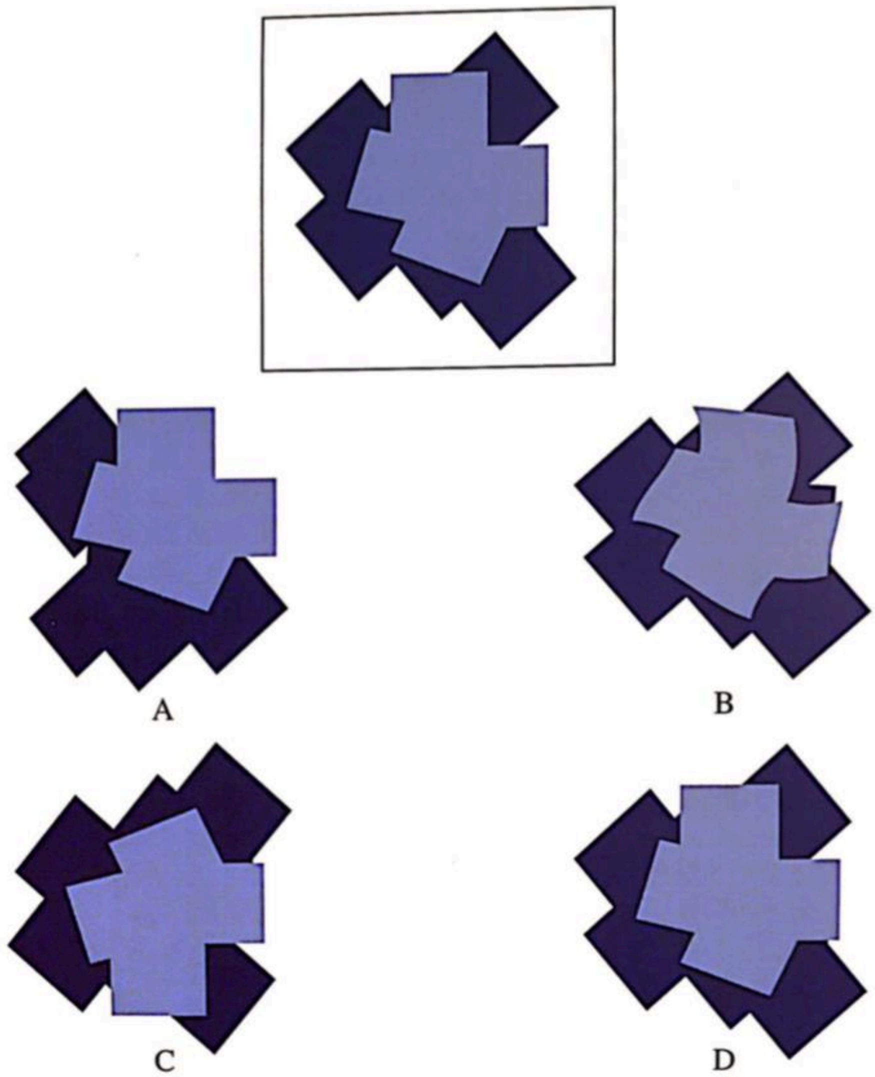
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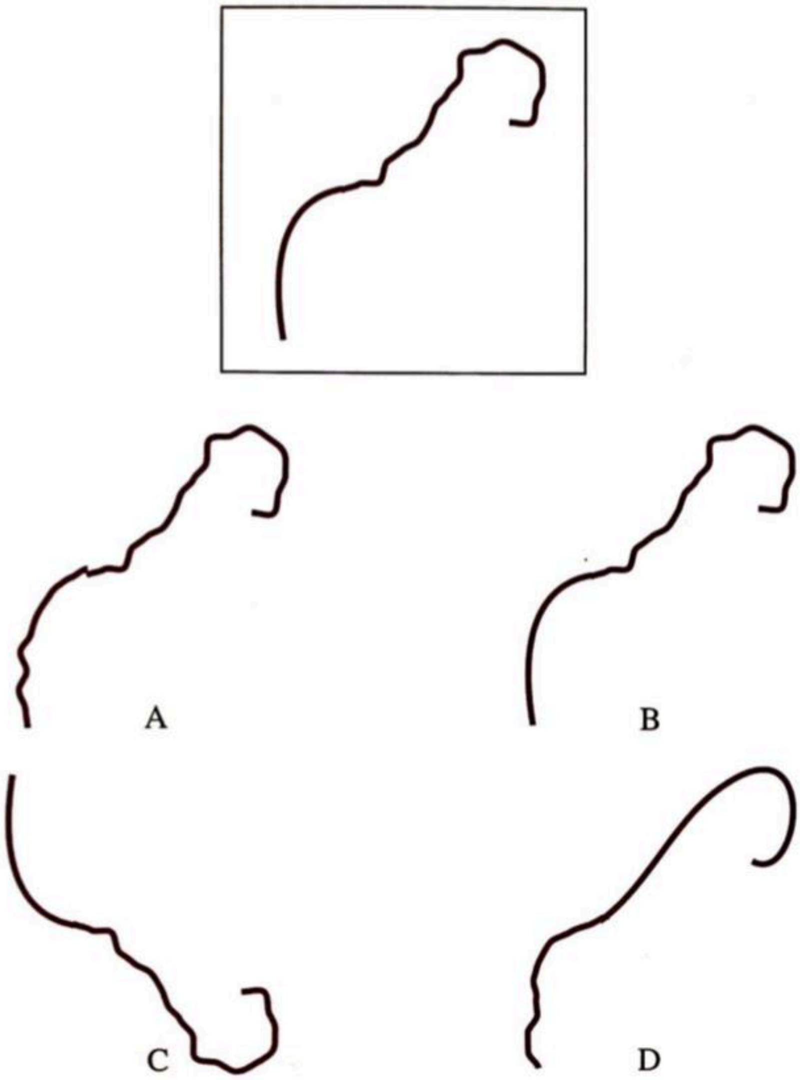
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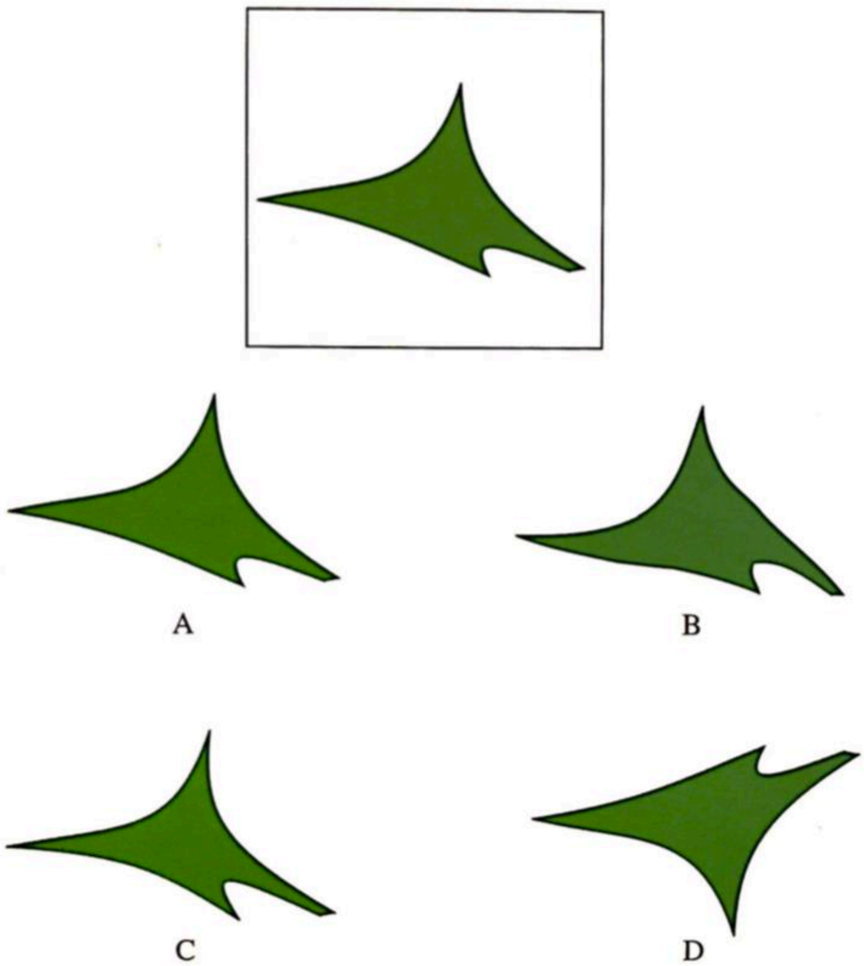
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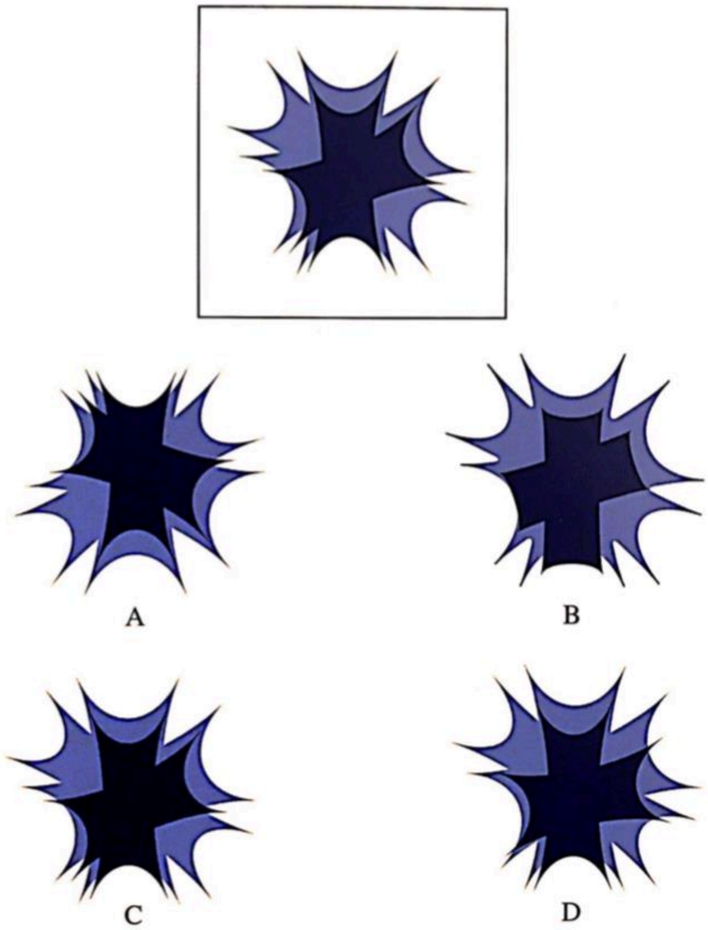

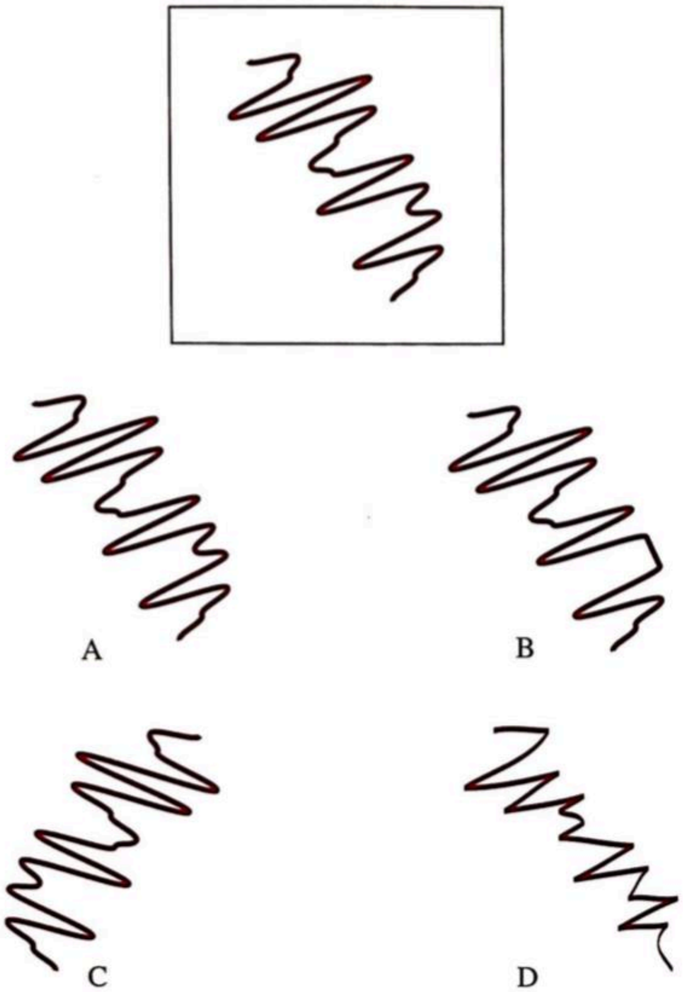
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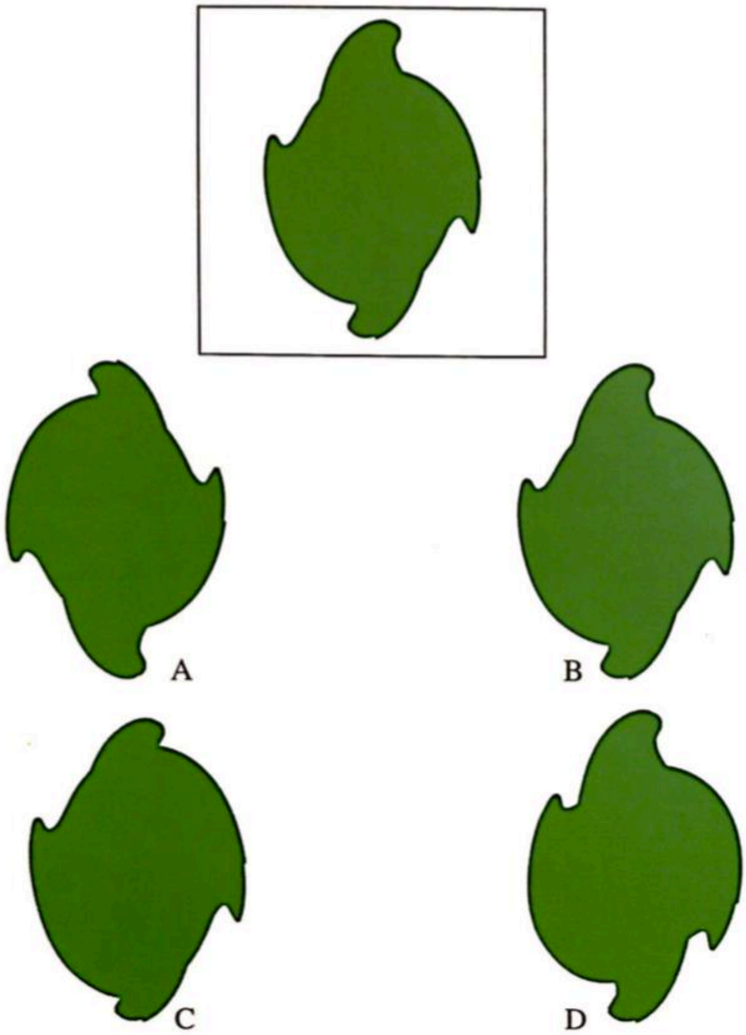
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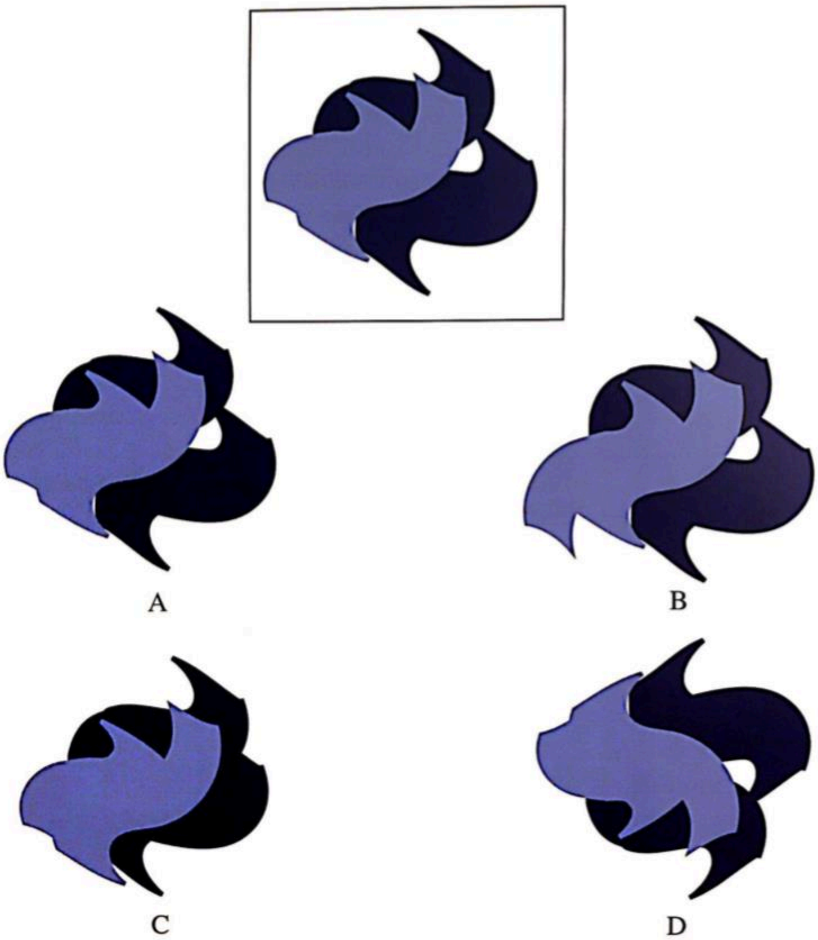
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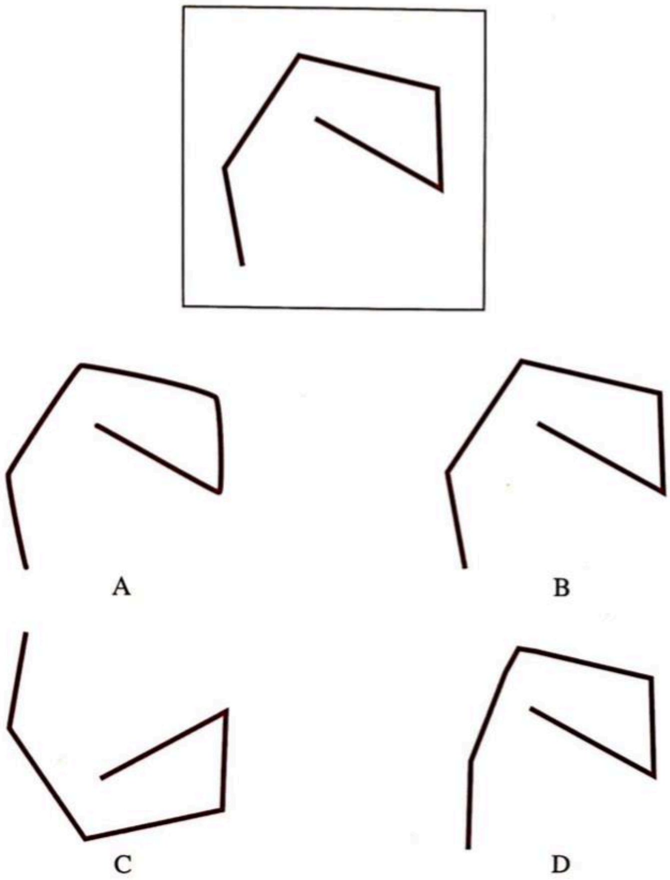
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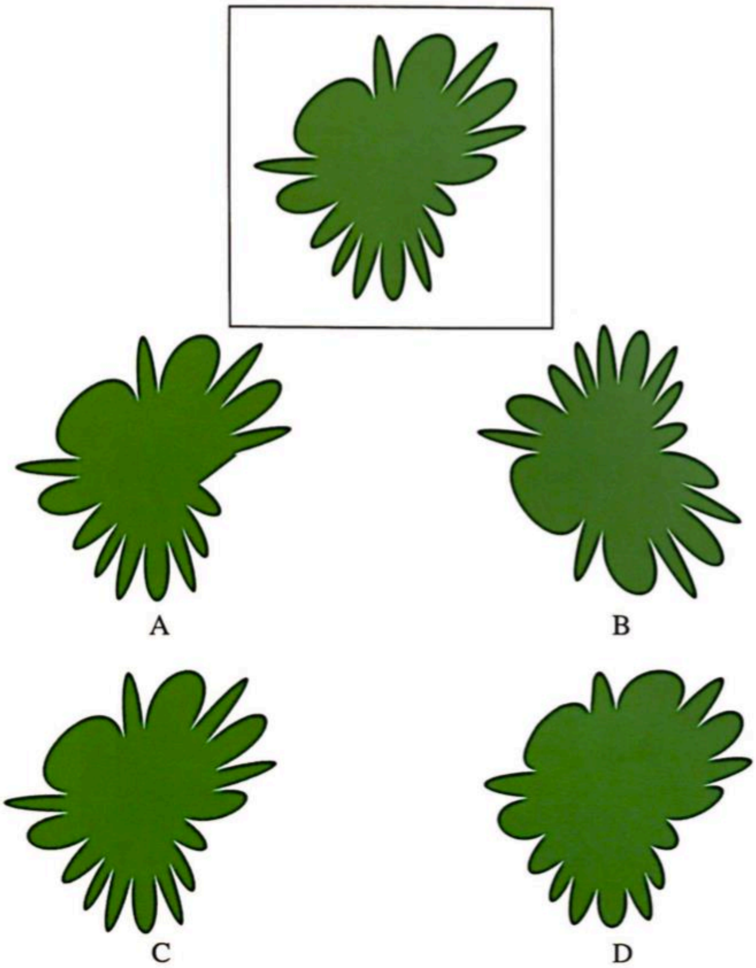
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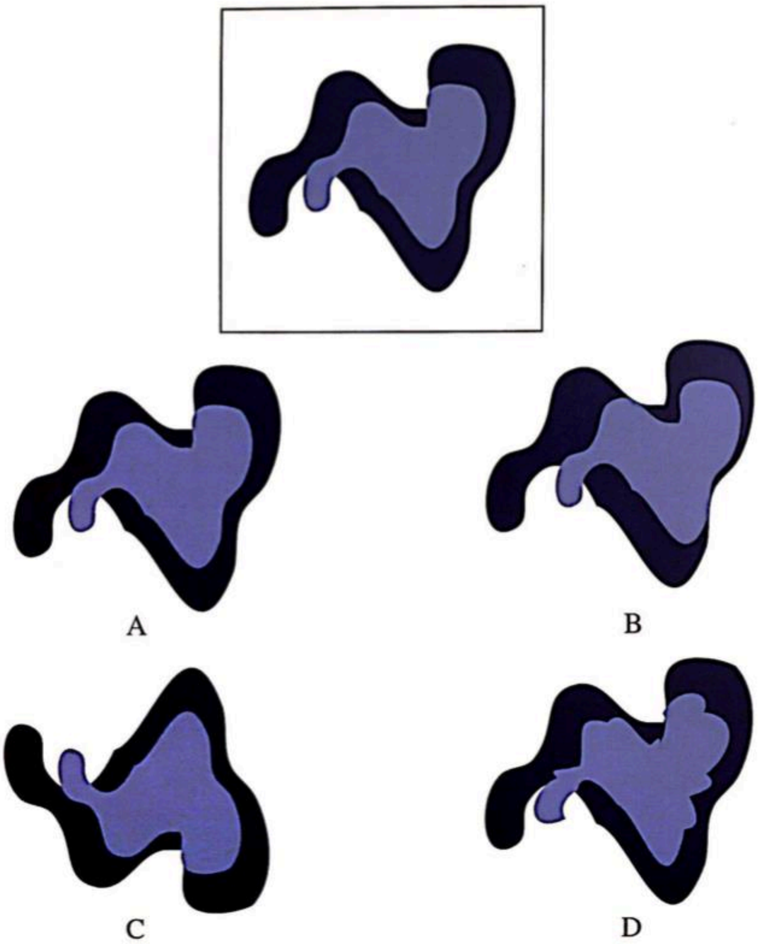
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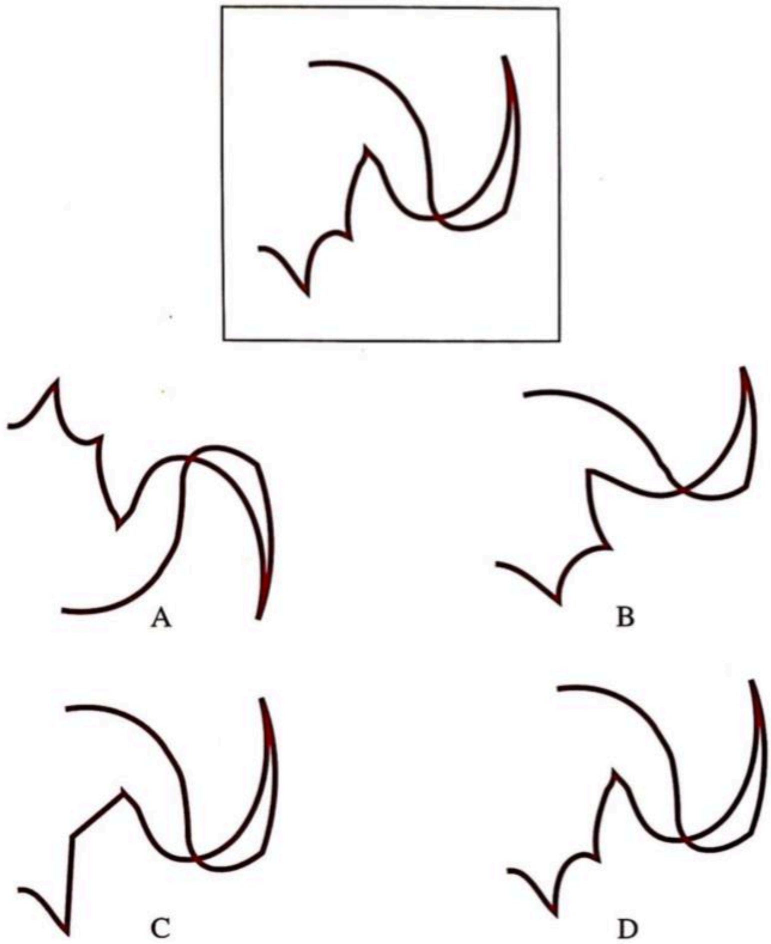
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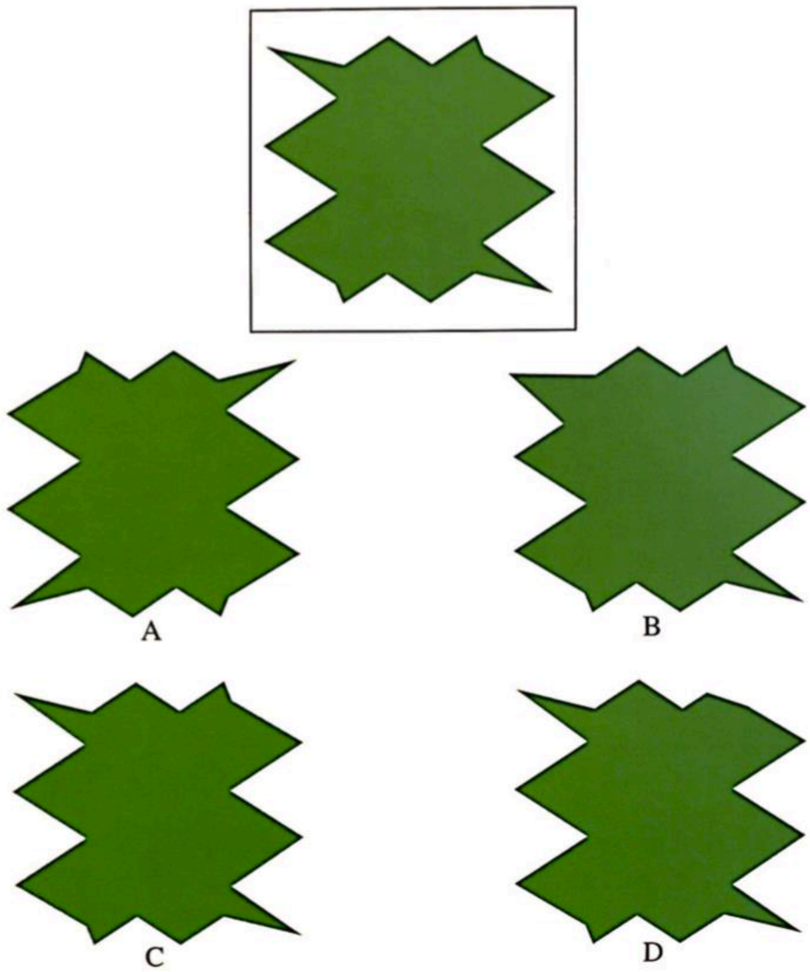
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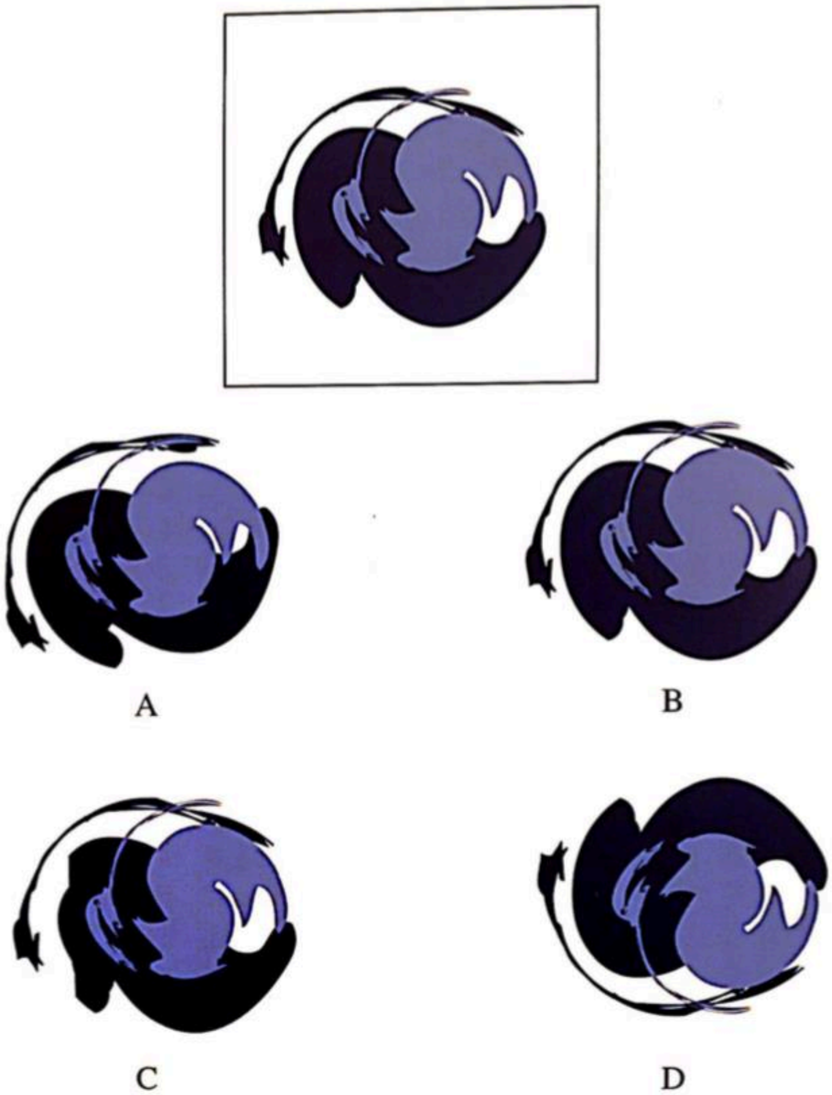
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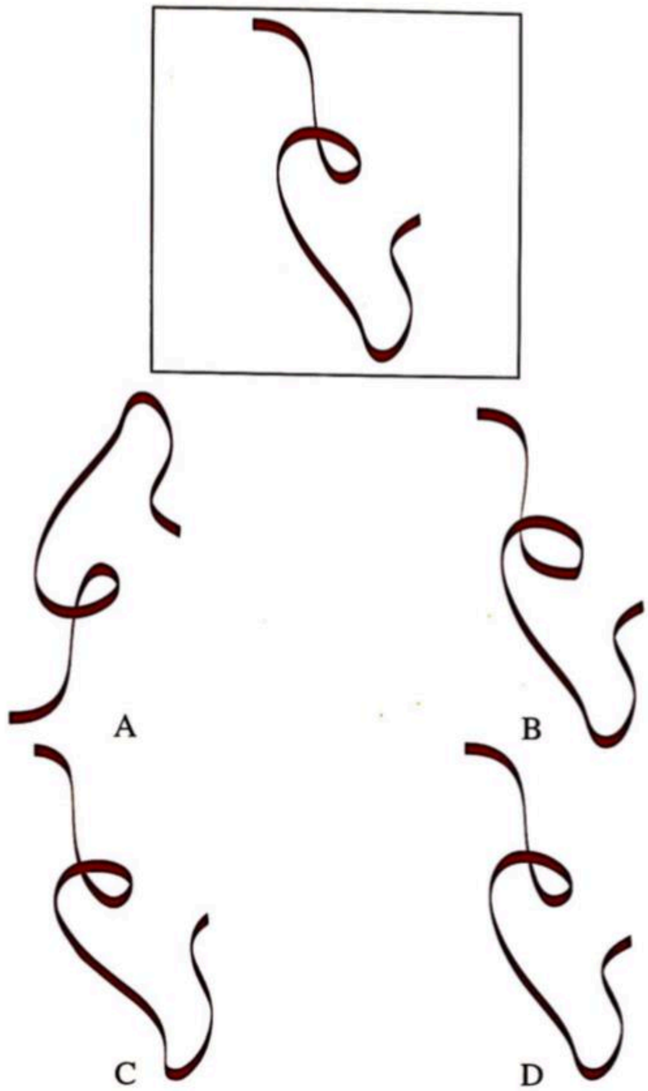
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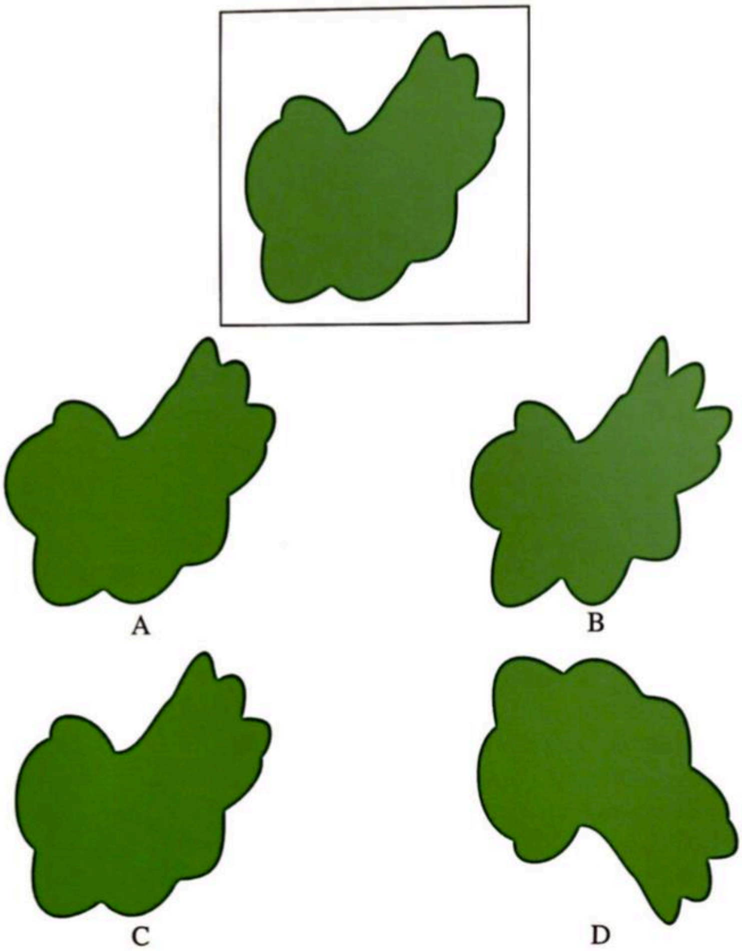
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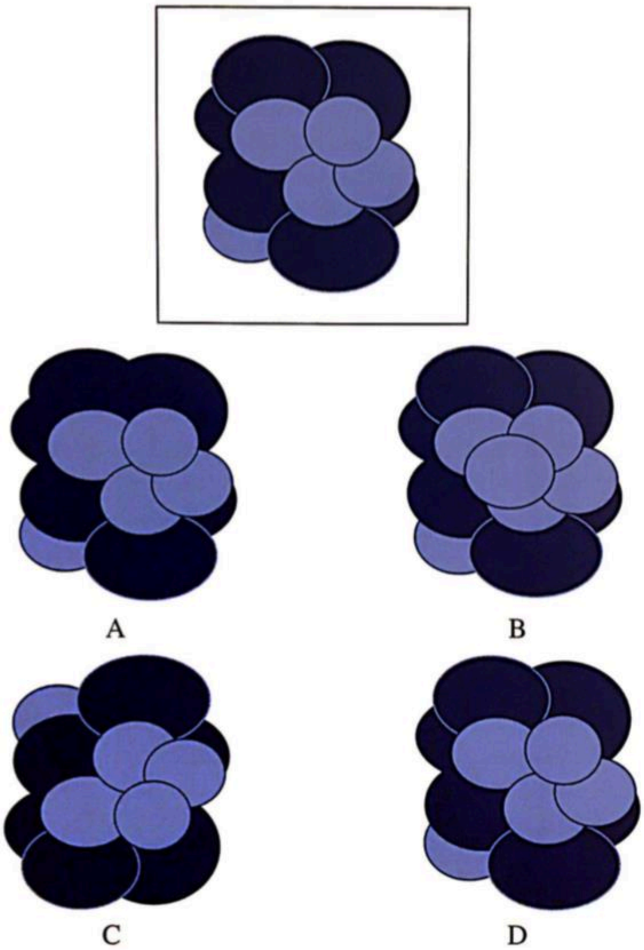
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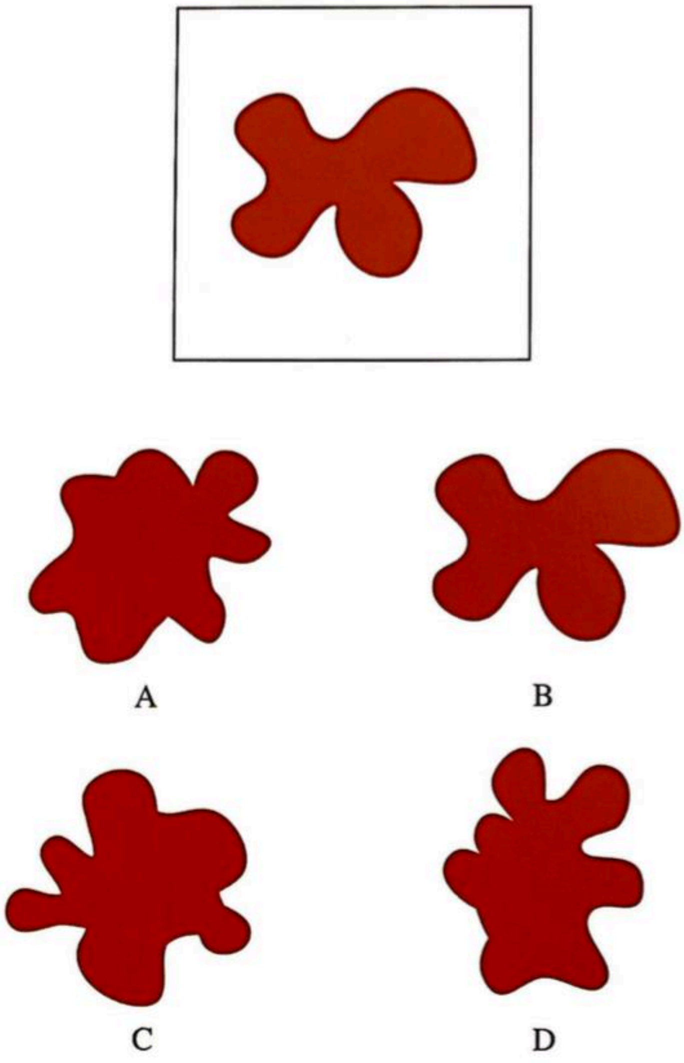
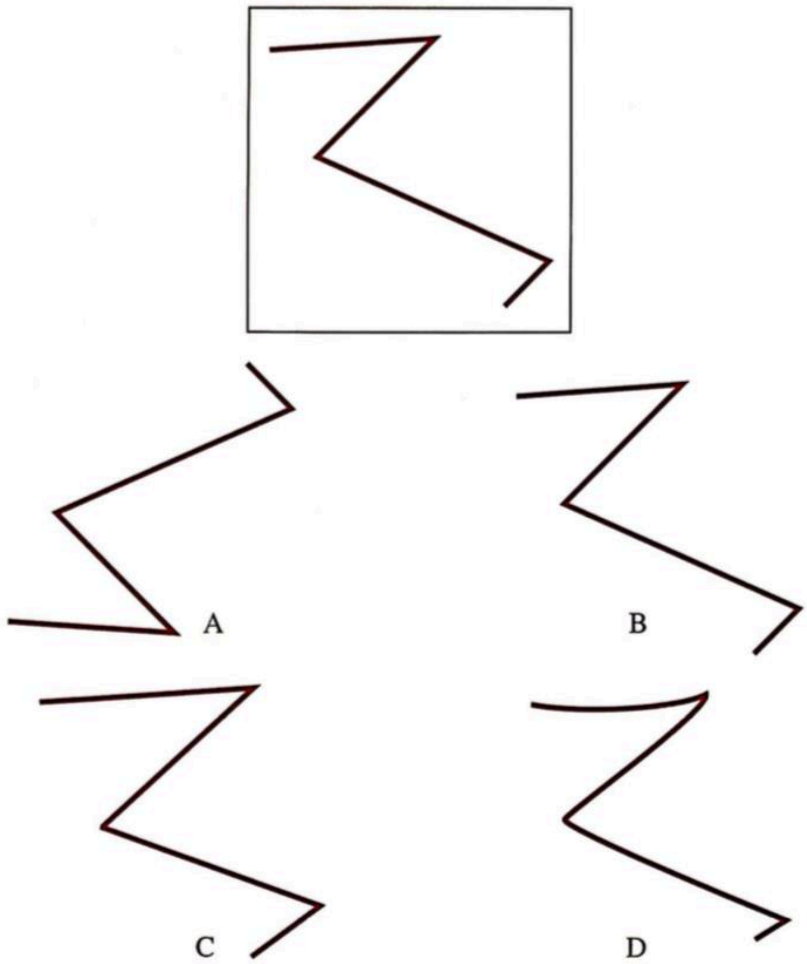
APPENDIX F - Visual Discrimination Stimulus (Book 2)

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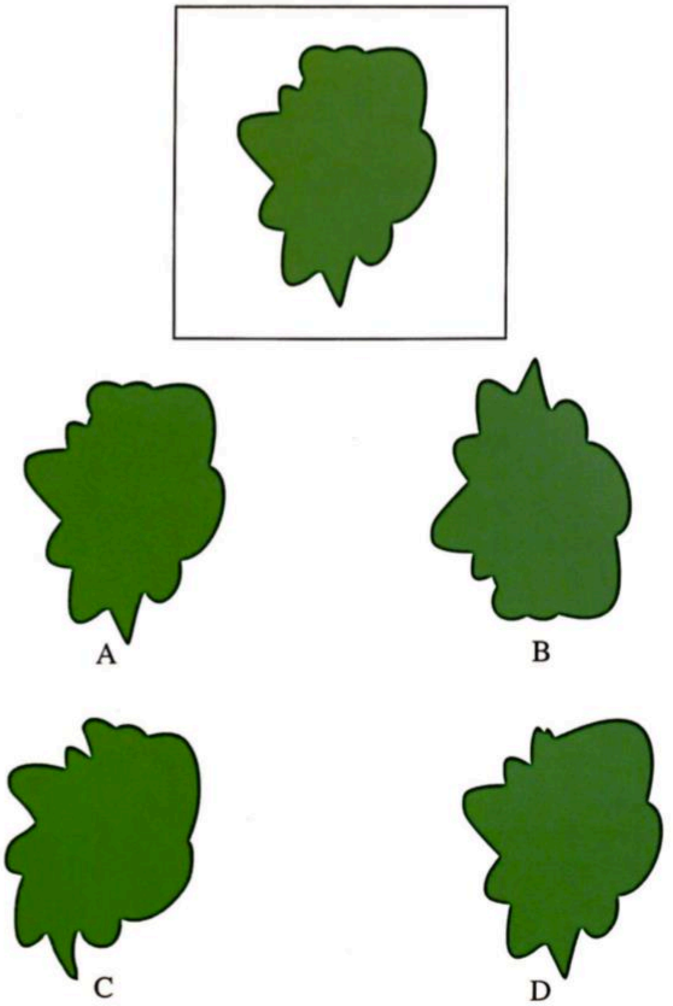
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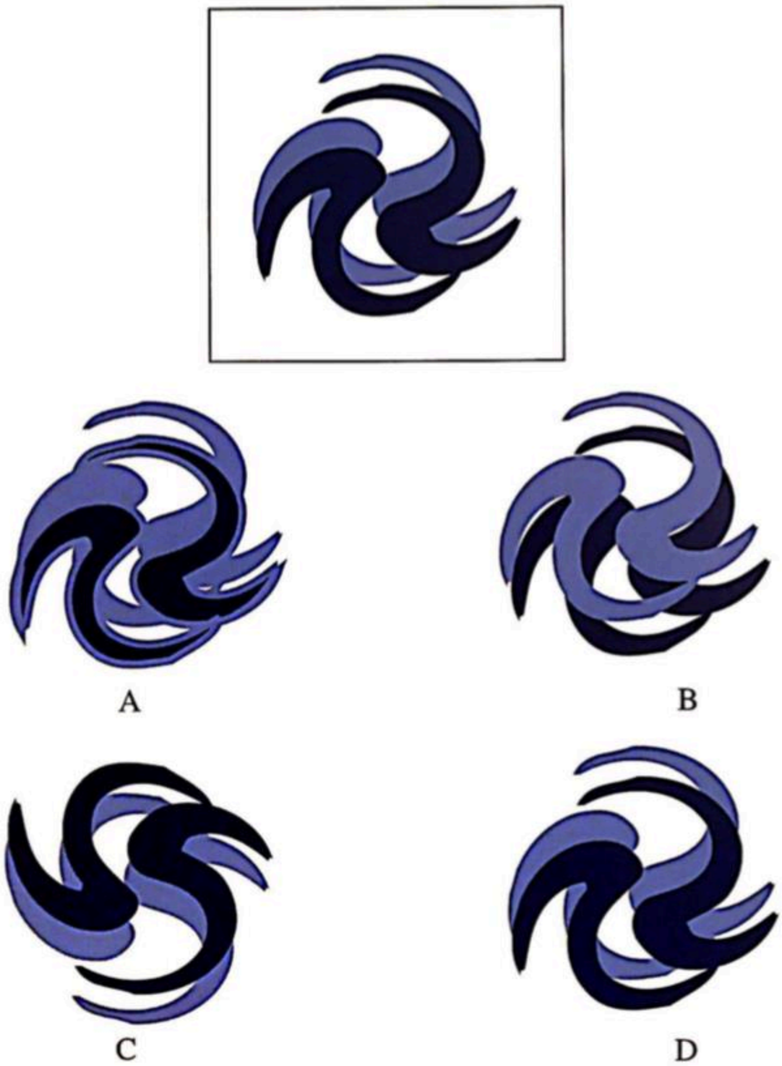
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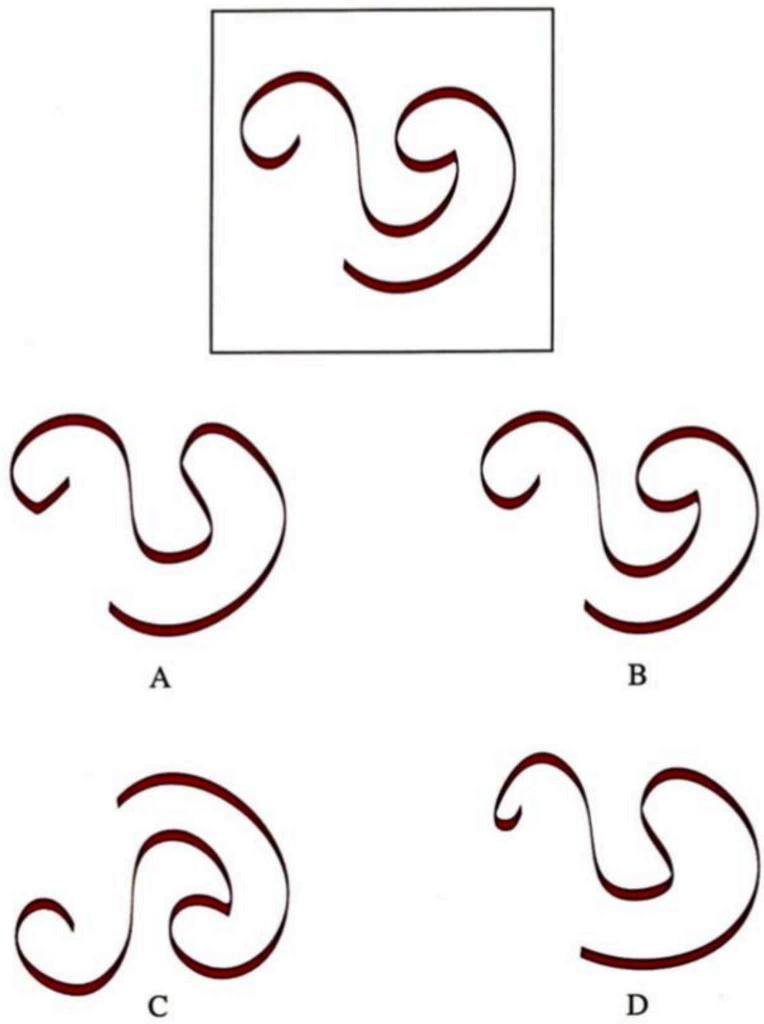
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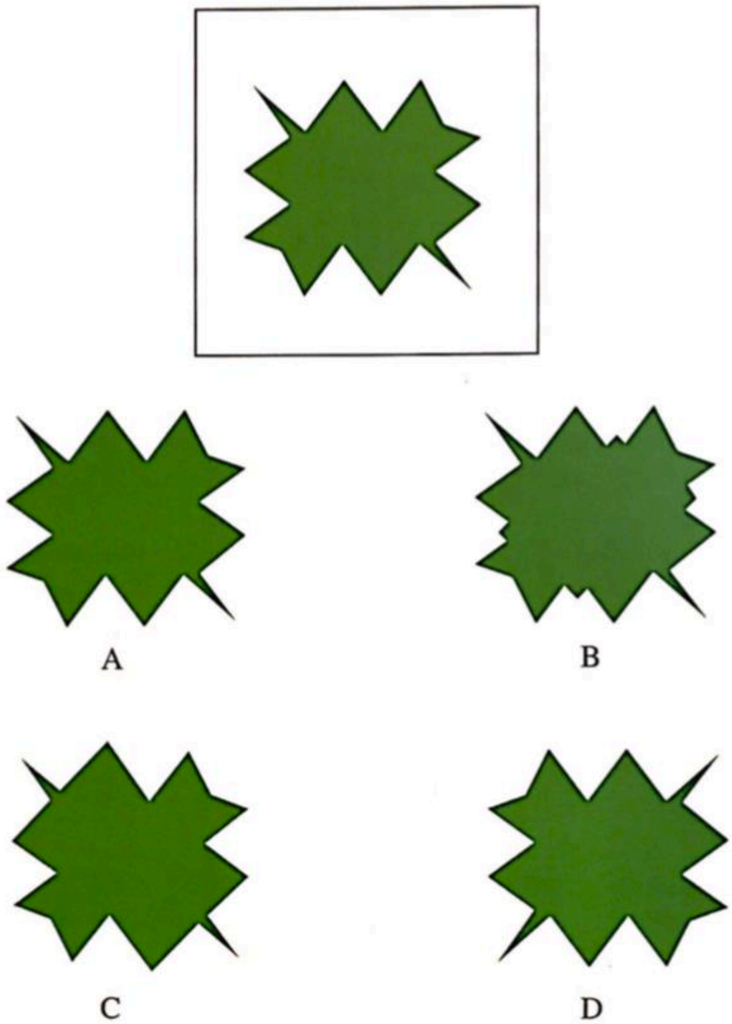
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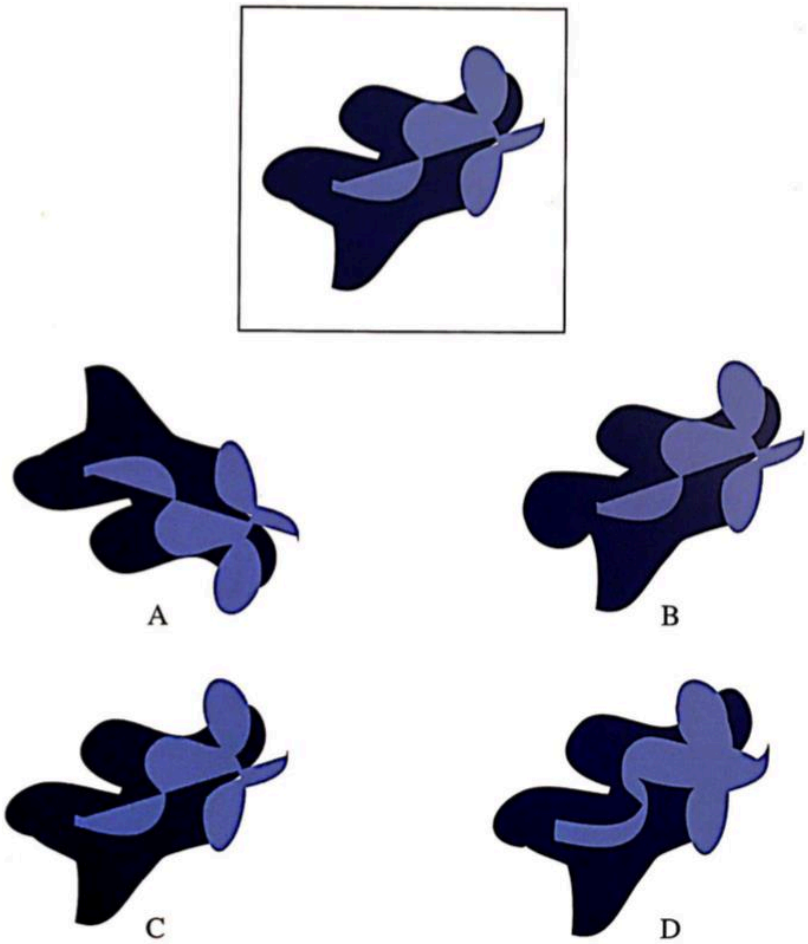
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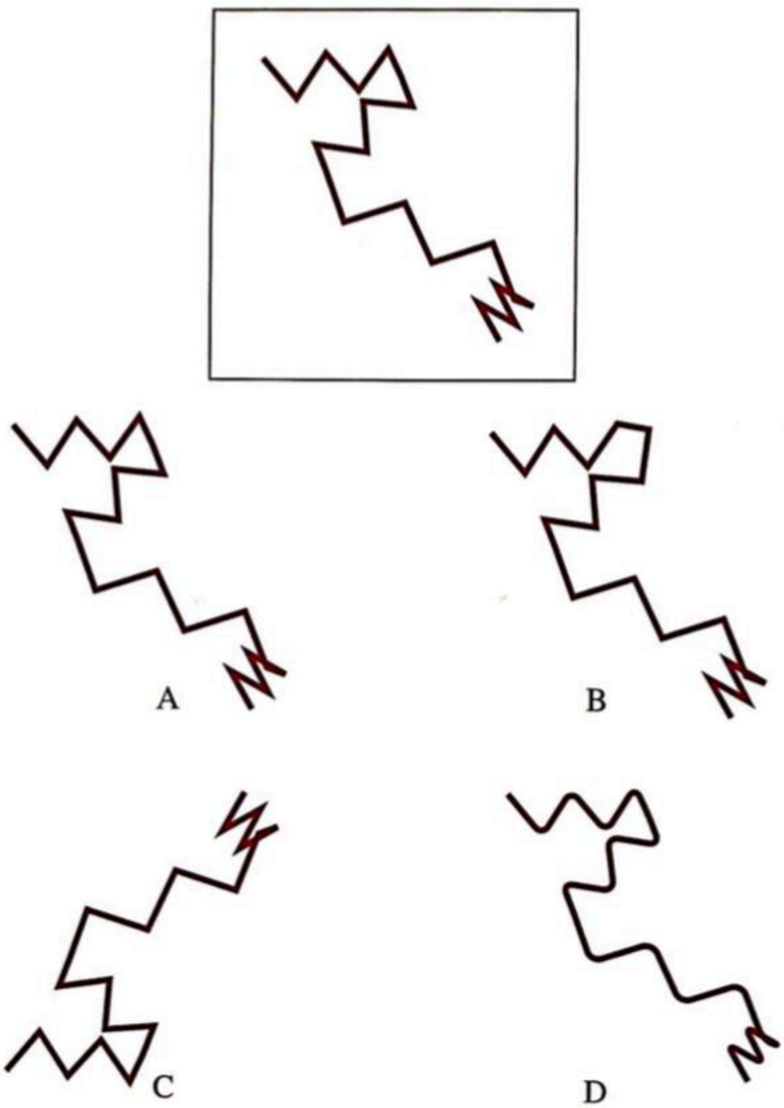
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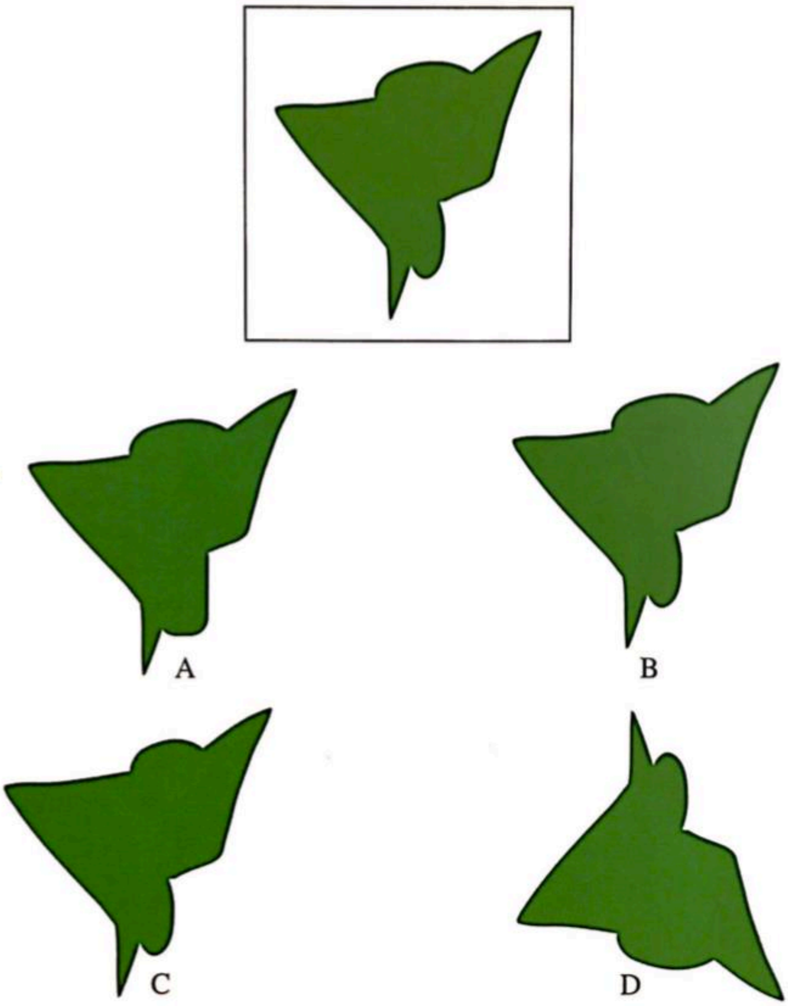
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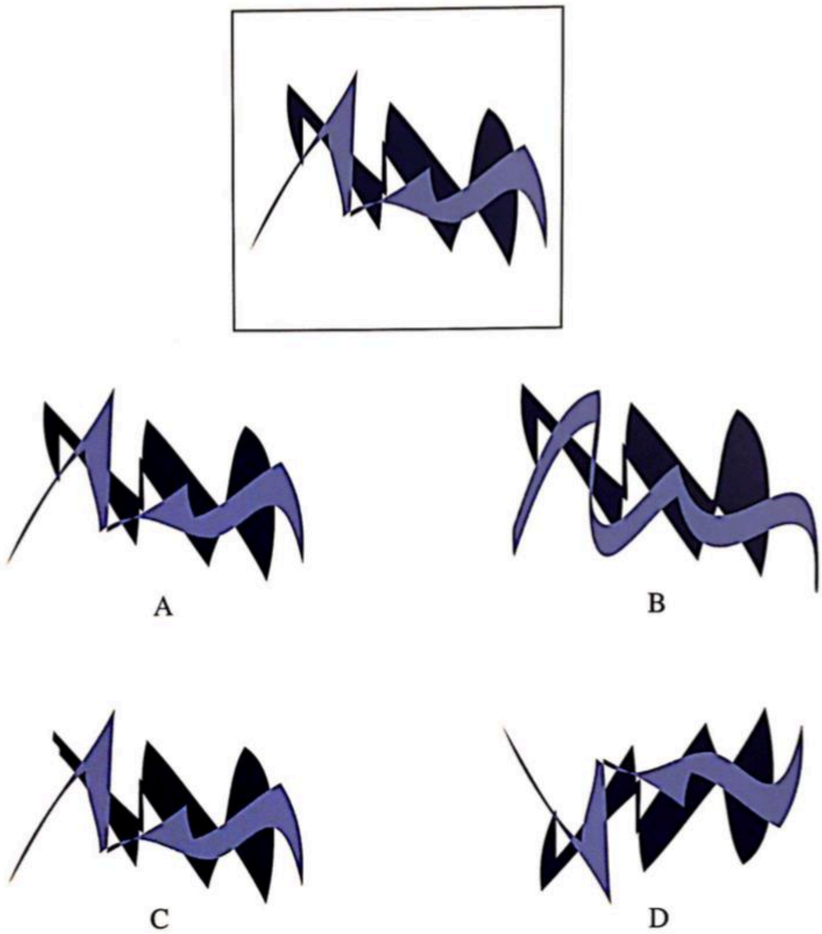
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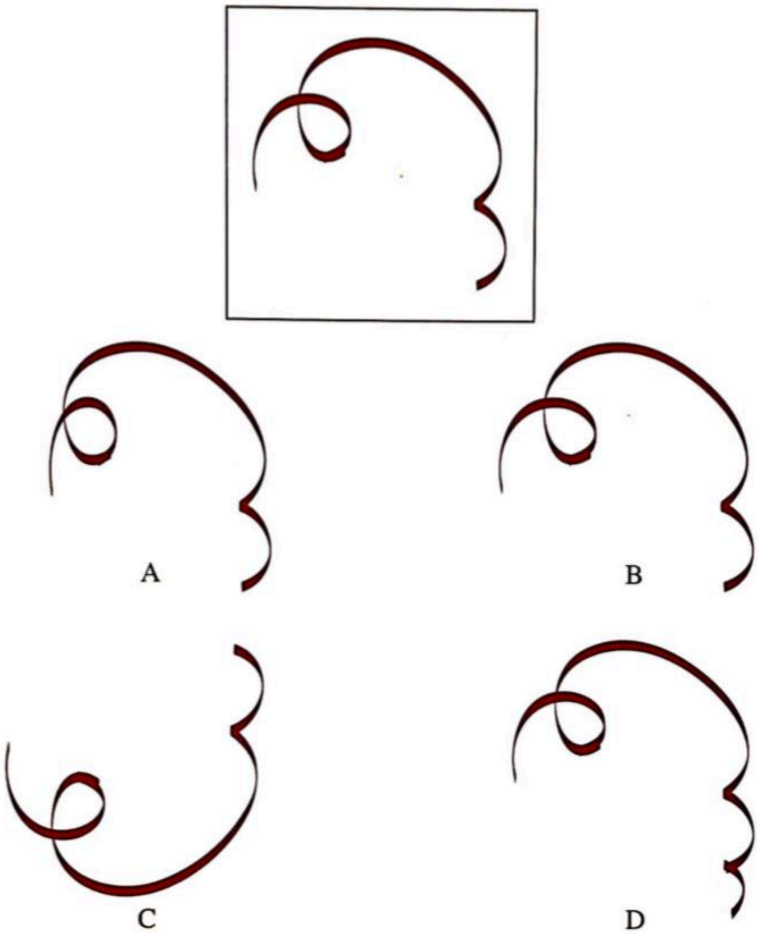
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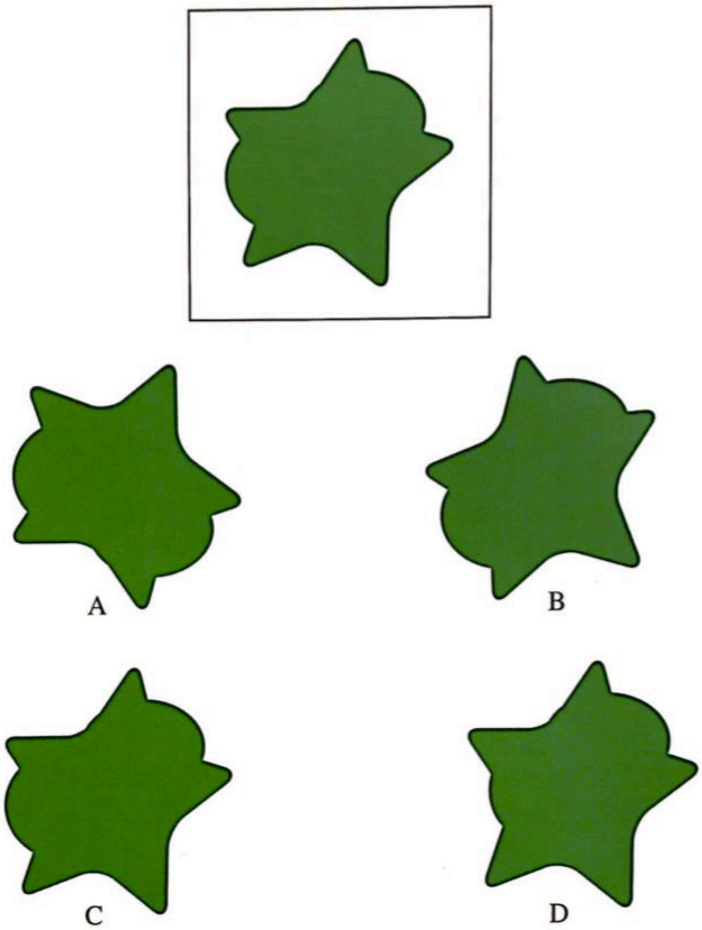
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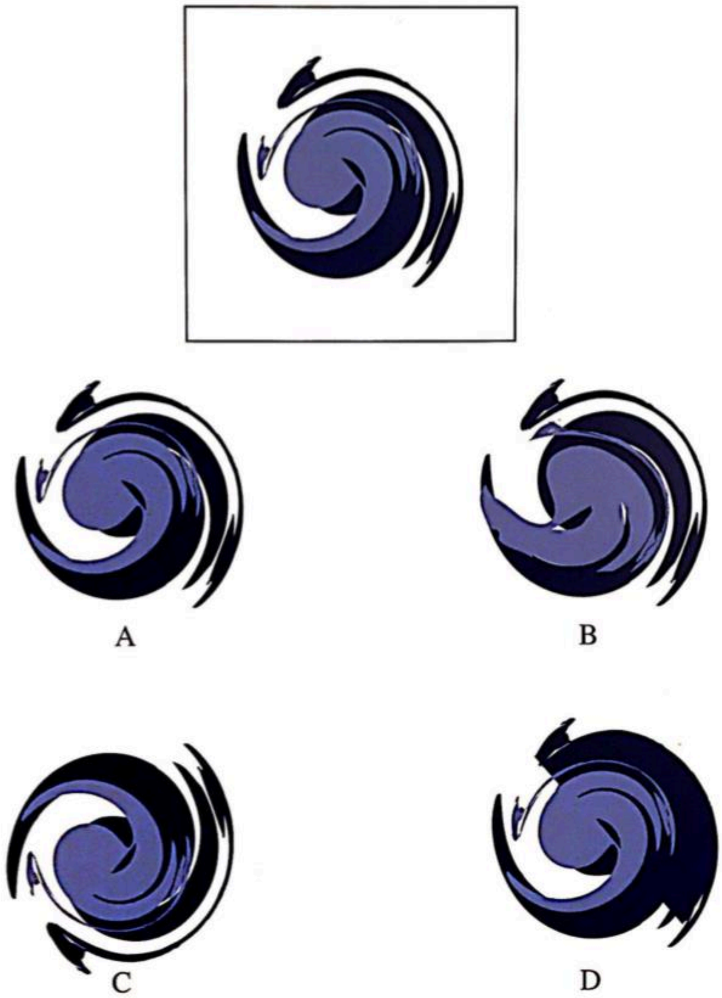
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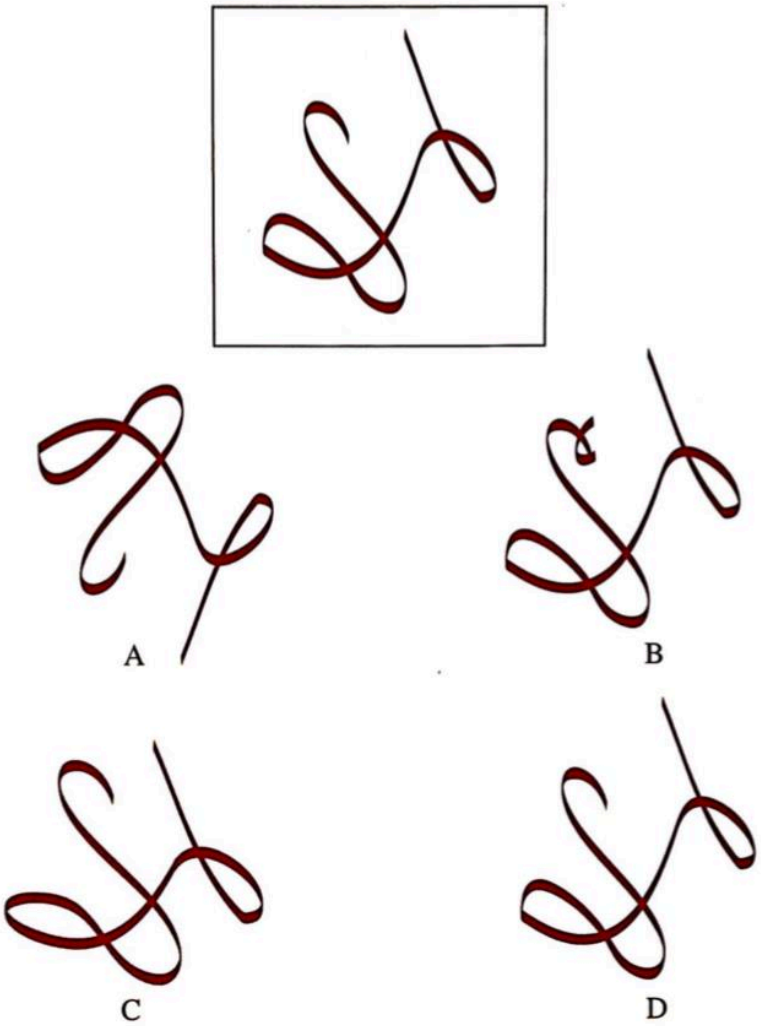
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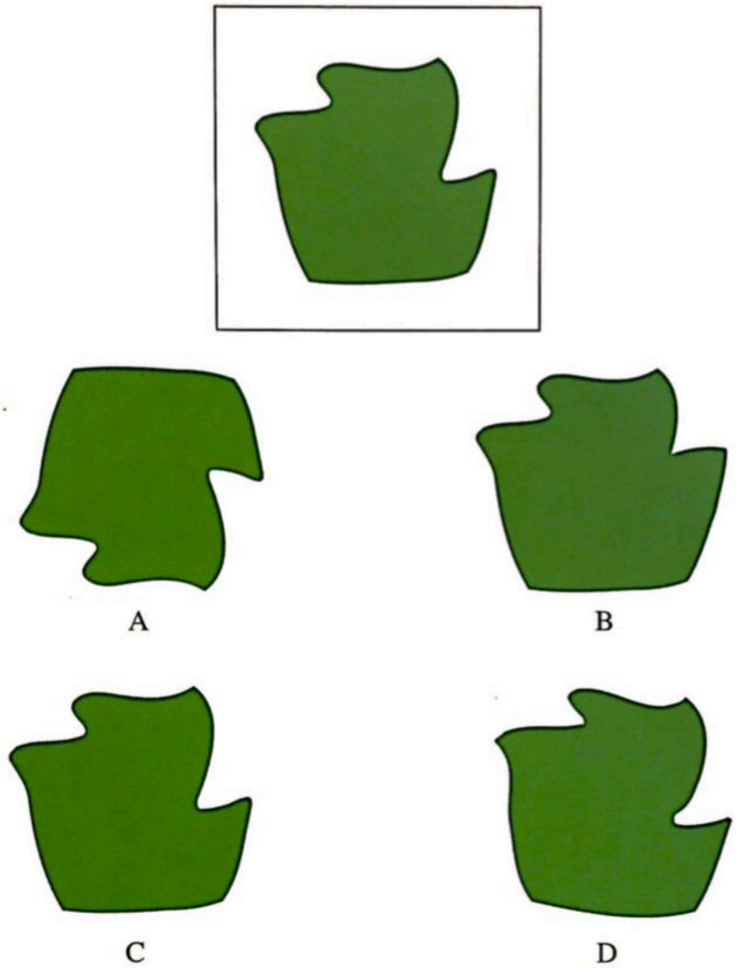
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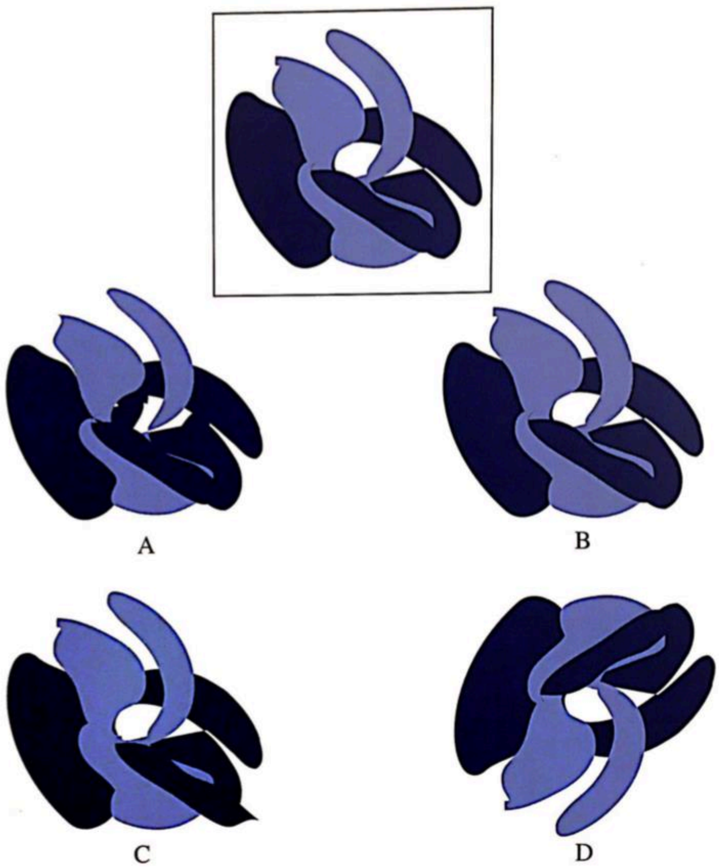
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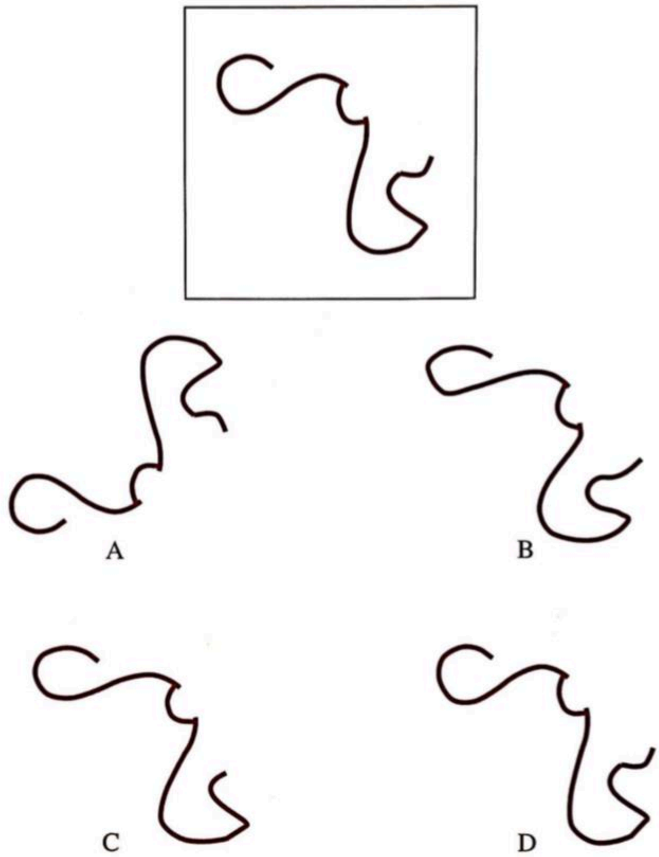
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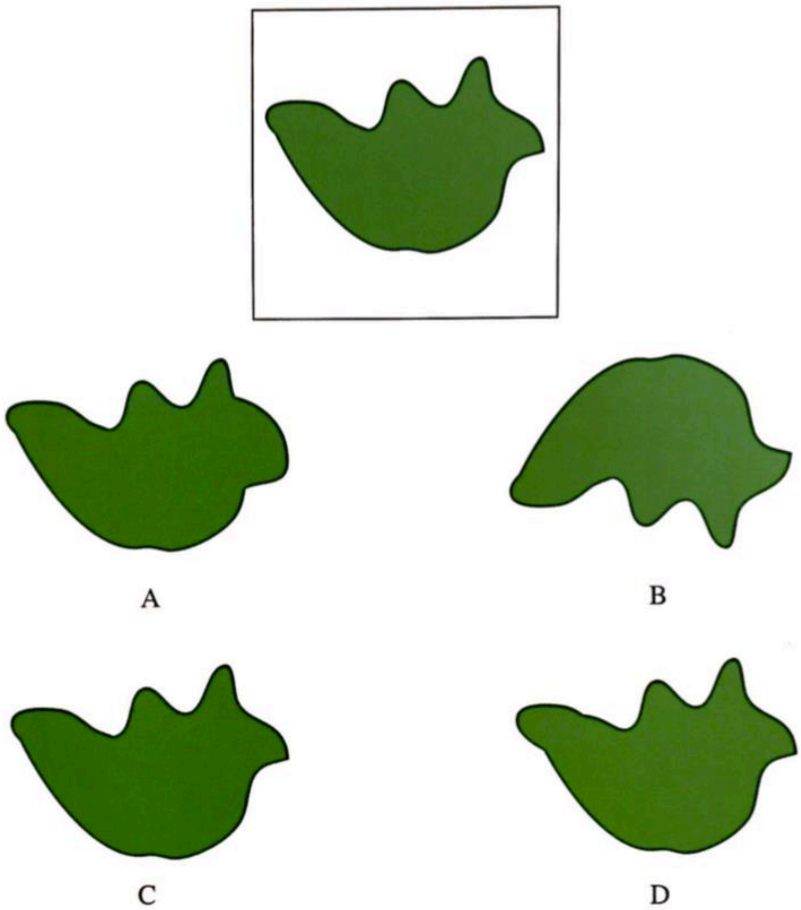
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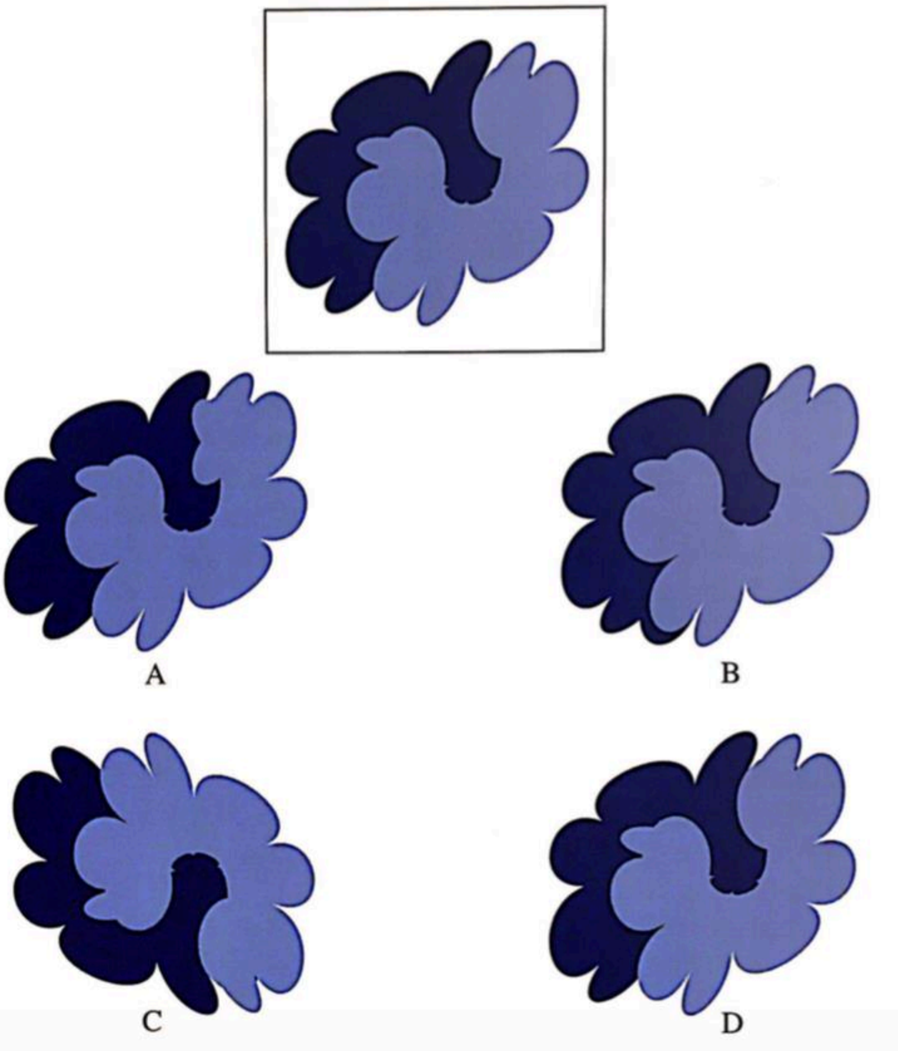
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