Interfering With Memory Retrieval: The Cost of Doing Two Things at Once

by

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Author’s Declaration

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

I understand that my thesis may be made electronically available to the public.

Abstract

A dual-task paradigm was used to infer the processes critical for episodic memory retrieval by measuring susceptibility to memory interference from different distracting tasks. Research suggests that retrieval interference occurs due to material-specific overlap between concurrent tasks. I tested whether interference could instead arise from processing-specific overlap. In Experiment 1, I took advantage of individual differences in how verbal materials could be represented in those with different language backgrounds. I compared recognition of studied information in English and Chinese speakers under full attention (FA) or under one of two different divided attention (DA) conditions. Participants viewed simplified Chinese characters or English words, and later completed recognition while simultaneously performing distracting tasks requiring phonological (DAP) or visuospatial (DAV) processing of auditorily presented letters. I found an interaction such that Chinese speakers were more susceptible to interference from the visuospatial than phonological distracting task, whereas the reverse pattern was shown in English speakers. These results suggest that interference with memory retrieval is processing-, not material-, specific, as both distracting tasks used the *same* materials. Next I sought to determine whether processing-specific interference could be observed within the visuo-spatial domain. Accordingly, in Experiments 2 and 3, I examined whether face recognition would be disrupted more by a distracting task requiring configural than featural processing. In Experiment 2, participants studied faces under FA and subsequently performed a recognition task under either FA or each of two different DA conditions in which a distracting face was presented alongside, requiring either a featural (DAF) or configural (DAC) decision. In line with a material-specific account of interference, face memory accuracy was disrupted in both DA conditions relative to the FA condition, although no processing-specific differences in interference were found *between* the DA conditions, likely because both distracting tasks engaged configural processing. To better isolate the different processing streams in Experiment 3, some faces were inverted to offset configural processing and to engage featural processing. I compared patterns of memory interference when target faces were presented upright (configural) or inverted (featural). I found a crossover interaction: memory for upright faces was worse in the DAC than in the DAF condition, whereas the reverse was true for inverted target faces, supporting a processing-specific account of memory interference. In Experiment 4, I sought to rule out task difficulty as an alternative explanation for the pattern of interference effects. I measured whether each distracting task produced similar slowing, which provides an indirect assessment of resource requirements of a task, on a simultaneously performed auditory tone discrimination task. Results showed that my distracting tasks were not differentially attention demanding, as indexed by similar accuracy rates for tone classification and response times on the tone discrimination task when performed concurrently with each distracting task. Findings suggest that the magnitude of memory interference under DA conditions at retrieval is influenced by material-specificity but that, critically, it also depends on the extent to which the processing demands of the distracting and retrieval tasks overlap. I have shown here that retrieval is not automatic or obligatory as others have suggested, but instead is subject to disruption. This thesis specifies that retrieval interference can occur due to competition for a limited pool of common processing resources across target and distracting tasks. Thus, when trying to recall studied information, one should avoid distracting conditions, especially those that overlap significantly not only with the type of materials tested but also with the mental processes required to retrieve that target information.

Acknowledgements

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Chapter 1: Interfering With Memory Retrieval: The Cost of Doing Two Things at Once

As we navigate the world before us, we experience a near constant input of multisensory information. Although this input seems to be seamless and cohesive, our processing abilities are not without limitations. We can only take in, store, and recall a finite amount of information at one time. Many have had the experience of attempting to study for an exam with the television or radio on in the background, or of trying to recall previously learned information while an intrusive conversation is occurring nearby. Both of these scenarios, reflecting memory encoding and retrieval respectively, can lead to memory impairments. Not surprisingly, the negative effects of multitasking on one's ability to encode and subsequently retrieve information have been extensively explored.

Thus far, however, researchers have focused almost exclusively on performance decrements for verbal stimuli (e.g., memory for word lists). Although the second chapter of this work used verbal material as well, I took a different approach in most of this thesis, and made use of inherent processing differences that arise as a result of language experience. Specifically, I aimed to determine whether the accounts of dual-task effects on memory for English words would apply to logographic languages as well, which are more visuospatial in nature. In the second chapter, I expanded generalizability of the claims of dual-task research beyond memory for English words. The applicability of these dual-task effects on memory, particularly to the visuospatial domain, remains largely untested. The third chapter was concerned with characterizing how memory for stimuli in this domain is affected by dual-task conditions during the retrieval phase of a memory task, to establish a more generalized understanding of the consequences multi-tasking presents to memory performance. Overall, the goal of the thesis was to determine the conditions under which memory retrieval breaks down, allowing us to further characterize what drives this process.

A Review of Past Studies of Divided Attention Effects on Memory

To understand the importance of studying the effects of multi-tasking on retrieval, it is necessary to review work that has been done in the past. Previous research suggests that the effects of doing two things at the same time, otherwise known in the research world as the effect of divided attention (DA) on memory, differ depending on whether the distraction occurs concurrently during the encoding or the retrieval phase of memory. In one classic example, participants were asked to complete a distracting card sorting task during encoding of a word list, or during subsequent retrieval (recall or recognition) (Baddeley, Lewis, Eldridge, & Thomson, 1984). Results indicated a staggering deficit as a result of divided attention during study or encoding. In contrast, effects during retrieval were either much less pronounced or non-existent. Accordingly, the researchers concluded that episodic retrieval, at least for words, was an automatic process. Subsequent work (Craik, Naveh-Benjamin, & Anderson, 1996) also showed negligible interference with memory performance under DA conditions at retrieval using a different task, which required classification of visually-displayed keyboard keys. Craik and colleagues, however, also considered data pertaining to distracting task performance, and found large costs to accuracy when completed under DA conditions. They concluded that although retrieval appeared to occur obligatorily in the sense that memory was minimally affected, it was not an ‘automatic’ process, but in fact was quite attention-demanding as indexed by the significant distracting task costs. Given that the prevailing view among memory researchers was that the retrieval process was in many ways similar to that at encoding (Kolers & Roediger, 1984; Morris, Bransford, and Franks, 1977; Tulving, 1983), these findings were particularly surprising, in that they displayed a stark contrast between effects of DA at encoding and those at retrieval.

Material-Specific Interference

The lack of a large effect at retrieval was quite puzzling, as retrieval is often conceived as an effortful process, often thwarted by distraction. Accordingly, further study was required to determine what conditions could make memory retrieval susceptible to interference under dual-task conditions. The possibility remained that previous research failed to find memory interference effects from DA at retrieval due to the relation, or lack thereof, of the chosen distracting tasks to the to-be-remembered information. Several camps within the fields of memory and attention have shown that performance on two simultaneously completed tasks may depend on the overlap or relation between the materials used in each (Pellegrino, Siegel, & Dhawan, 1975; Wickens, 2008). Fernandes and Moscovitch (2000) showed that the magnitude of memory interference depended on whether the material in the distracting task and in the target memory task overlapped. During recall of studied words, participants simultaneously performed either a digit-based or equally difficult word-based distracting task. Although the digit task led to a small recall detriment comparable to previously reported work, the word-based distracting task produced a substantial 30% decrease in recall from full attention (FA) levels.

With this and many additional studies showing similar effects (Dudukovic, Dubrow, & Wagner, 2009; Healey & Miyake, 2009; Lozito & Mulligan, 2005; Luo & Craik, 2009; Rohrer & Pashler, 2003; Wais, Rubens, Boccanfuso, & Gazzaley, 2010), it was proposed that interference with the retrieval process was material-specific (Fernandes & Moscovitch, 2000). They suggested that others failed to find large memory interference effects from DA at retrieval because the materials in their chosen distracting tasks were spatial (Craik et al., 1996) or digit based (Baddeley et al., 1984) and thus were dissimilar to those in the word-based memory task. To clarify, large interference effects were observed only in circumstances in which the to-be-remembered information and the distracting task were competing for a common material set, or representational system (Fernandes & Moscovitch, 2000). The generalizability of this claim, however, is limited because in most of these previous studies, only memory for words was assessed. In other words, the findings may not apply to alternative stimulus sets that are processed differently than English words. The current research extends the study of the effects of DA to more diverse verbal stimuli using Chinese characters (in Chapter 2), but more broadly to the visuo-spatial domain (in Chapter 3) by examining conditions which lead to differential interference with memory for faces.

Interference with Short-Term Memory

Although the commonly held belief is that retrieval interference is material-specific, recent evidence suggests that overlap in the type of processing required may play a role as well (Fernandes & Guild, 2009). The idea of processing-specific (as opposed to material-specific) interference with memory performance should sound familiar, as it has previously been applied to retention during a short-term memory task. Motivated by Paivio’s (1971) dual coding theory, which holds that to-be-remembered information can often be represented both verbally and visually, Pellegrino, Siegel, and Dhawan (1976b) tested whether short-term memory was differentially affected by distraction, depending on whether the encoded information was verbal or visual. Results across several experiments indicated that acoustic distraction led to a larger reduction in short-term memory for words than pictures, whereas visual distraction displayed the opposite outcome (Pellegrino, Siegel, & Dhawan, 1975; 1976a, 1976b).

These findings are in line with the Baddeley and Hitch (1974) framework of working memory as a multicomponent system. According to the authors, working memory can be broken down into constituent parts, each of which processes specific classes of stimuli and is sensitive to suppression from different sources. The phonological loop deals with rehearsal of verbal information, and thus can be interfered with by articulatory suppression (Alloway, Kerr, & Langheinrich, 2010; Toppino & Pisegna, 2005). This has clear applications to the encoding of word stimuli, as it represents a phonological 'distracting task' interfering with memory for verbal information. Conversely the visuo-spatial sketchpad acts as a processor for visual stimuli. Thus, the sketchpad would be engaged directly in memory for pictures as well as other visuo-spatial stimuli (e.g., faces or logographic stimuli such as Chinese characters) (Kemps & Tiggeman, 2007). Although interference as a result of within list competition from semantically (Baddeley & Dale, 1966) or acoustically (Baddeley, 1966) similar stimuli has been explored, of note for this thesis, the idea of competition for common processing resources has not been extended from short- to long-term memory.

Processing-Specific Interference

Recent work in the study of memory has lent support to the notion that competition for limited processing resources may produce similar striking consequences for long-term memory performance as it does for short-term memory. Recent research has alluded to this alternative locus for retrieval interference, at the level of common processing requirements rather than common materials. Fernandes and Guild (2009) examined memory for visuo-spatial grid patterns, or for words, with retrieval completed under full attention (FA) or two different DA conditions in which the distracting task material consisted of letters heard through speakers. Importantly, in each of their DA conditions, different processing was required of the letter distractors: either visuo-spatial (does it contain a curved line?) or phonological (does it rhyme with ‘e’?). An interaction was found such that the visuo-spatial distracting task produced more interference with retrieval of the visuo-spatial grids than did the phonological task, whereas the opposite was true when the target retrieval information was words. This interaction is consistent with the possibility that similarity in processing requirements across target and distracting tasks may play a role in mediating the magnitude of retrieval interference.

Fernandes and Guild (2009) used visuo-spatial material as their memory stimulus; however, there are obvious drawbacks to their chosen stimulus set. Because visuo-spatial grids such as the ones they used are not commonly experienced or familiar, they are not an ideal comparison for verbal stimuli, which we use daily. As a first attempt at further examining this processing-specific locus of retrieval interference, I inserted a more commonly experienced stimulus set in the place of visuo-spatial grids. I studied persons who were adept at reading English (monolinguals) and persons who were adept at reading both English and Chinese (bilinguals). For these bilingual participants, retrieval of simplified Chinese characters (tested in Mandarin speakers) was compared to retrieval of English words (tested in English speakers) under FA and DA conditions to determine whether overlap in the type of processing required produced interference. Comparing retrieval interference for alphabetic and logographic languages also served to test whether the material-specific effects shown in previous studies applied across diverse sets of verbal stimuli.

Evidence from Neuroimaging

For there to be competition for processing resources between two tasks, these tasks must be completed simultaneously. Some argue that two tasks cannot be simultaneously completed, and that a bottleneck occurs, leading one task to be delayed until the other is complete (Pashler, 1989). Evidence from neuroimaging research, though (Klingberg & Roland, 1997), strengthens the claim that two tasks performed at the same time lead to interference by showing that when two tasks require the same brain area, as do common materials (Bunzeck, Schütze, & Düzel, 2005; Prince, Dennis, & Cabeza, 2009), detriments to performance are large. It was also shown that the degree of behavioral interference corresponded to the degree of cortical overlap (Klingberg & Roland, 1997). These neuroimaging findings however, allow for the possibility that it may not be the materials that are most important in determining interference: It could be the type of processing required of the materials that produces overlapping activation patterns, and hence interference. In other words, if stimuli for two different tasks used the same materials, but required different types of processing (e.g., phonological vs. spatial; featural vs. configural), it is possible that the overlap in activation would not be as extensive as when two tasks used the same materials and required the *same* type of processing. Because the extent of cortical overlap can determine task interference (Klingberg & Roland, 1997), it is possible that a processing-specific account may better explain dual-task interference than does a material-specific account alone.

Queuing versus Sharing

It is important to consider alternate models of the mechanism underlying dual-task effects, before presenting evidence in favor of my proposed account. Pashler (1989; 1990) proposed a two component theory of dual-task interference. In this alternate account, performance decrements were explained by a combination of a ‘response-selection bottleneck’, whereby a response on one task had to await completion of response selection for the first, and ‘capacity sharing’, whereby limited attentional resources are depleted by a distracting task. The latter of the two components seems to be in line with the material-specific account of Fernandes and

Moscovitch (2000). This account operates under the assumption that two tasks are processed concurrently, which can lead to interference if both tasks involve the same materials. Pashler’s research (1990; 1994) however, suggested that the bottleneck account, rather than capacity sharing, better explained the slowed reaction time during dual-task experiments. Some more recent work however, suggests that capacity sharing between simultaneous tasks cannot be ruled out as a viable contributor to observed dual-task deficits (Rohrer & Pashler, 2003; Ruthruff, Pashler, & Hazeltine, 2003). Further, recent research (Navon & Miller, 2002; Tombu & Jolicoeur, 2003) has provided support to the notion that two concurrent tasks can indeed compete for resources, regardless of a response selection bottleneck. This work lends credence to accounts which involve simultaneous processes (capacity sharing, material-specific or processing-specific accounts) rather than a simple queuing of tasks (bottleneck), where one task simply awaits completion of the other. The current work will explore the consequences of this concurrent task completion for memory performance.

Chapter 2: Interfering with Language Representations

Based on previous findings (Fernandes & Guild, 2009; Fernandes & Moscovitch, 2000), one could theorize that because words are primarily processed phonologically, distracting tasks that emphasize phonological processing will always produce more interference than distracting tasks that require other types of processing, be they numerical or visuo-spatial. The purpose of the current chapter is to determine the consistency of this generalization across different verbal materials. One possibility is that it may hold true only for alphabetic languages (such as English) that rely on a high grapheme-phoneme correspondence (Chen & Yuen, 1991). In these languages, the smallest orthographic unit, a grapheme, corresponds to a phoneme in a predictable and patterned way, allowing a rapid transition from orthography to phonology. Language processing is, however, a learned way to represent information that varies by culture. What would be the pattern of interference when the to-be-remembered stimuli are from a logographic language such as Chinese? This language differs from English in how words are represented, using a set of symbols or characters rather than letters. Characters do not encode phonemes, but rather full syllables and words; thus the correspondence between the printed stimulus and speech is not as clear (Perfetti, Nelson, Liu, Fiez, & Tan, 2010; Qian, Reinking, & Yang, 1994; Tan et al., 2001).

How are Simplified Characters Processed?

Although some phonetic information is carried in the phonetic radical of the characters, it is incomplete, and the mapping from the phonetic component to the word’s pronunciation is not as clear as in most alphabetic languages (Chen & Yuen, 1991; Christensen & Bowey, 2005). To clarify, the relation between the pronunciation of a character and its phonetic component is often ambiguous and inconsistent (a phonetic radical is consistent if all characters containing the phonetic component have the same pronunciation; see Feldman & Siok, 1999; Zhou 1978; Hsiao & Shillcock, 2006). Further, due to the high incidence of homophones in Chinese (up to 12 for some words (Tan & Perfetti, 1997), words cannot be reliably distinguished by pronunciation, and the meaning of a word can be attained using its semantic components often with little input from phonology (Perfetti et al., 2010; Tan & Perfetti, 1997; Zhang, Xiao, & Weng, 2012). Thus, the extraction of phonology from orthography in Chinese is typically not as transparent as that in alphabetic languages. The convergence of these factors leads those proficient in reading Chinese characters to rely more on a visuo-spatial mode of representation when processing these characters (Huang & Hanley, 1994; Tan, Laird, Li, & Fox, 2005).

Evidence from behavioral research supports the notion that Chinese word processing relies more on visual than phonological processing. For example, in a similarity judgment task, Chinese-speaking participants were shown a target word written as a simplified character while it was simultaneously read aloud to them. They then completed a forced choice between two characters, one of which was visually similar and one of which was phonologically similar to the target. Chinese participants favored the visual choice, suggesting that they encoded the initially-presented Chinese character more visually than phonologically (Chen & Yuen, 1991).

These findings are bolstered by correlational studies that indicate visuospatial abilities such as handwriting of characters, pseudo-character copying, and picture drawing in Chinese children are more strongly correlated with reading ability of Chinese characters than are phonological discrimination tasks (Huang & Hanley, 1994). Such research suggests that Chinese characters are skewed toward a visuo-spatial mode of representation, whereas other research suggests representation of English words requires more phonological processing (Adams, 1994; Jared, Levy, & Rayner, 1999; Lee, Binder, Kim, Pollatsek, & Rayner, 1999; Lesch & Pollatsek, 1998).

The current study explored whether memory retrieval interference patterns mirror this dissociation in the representation of Chinese characters versus English words.

Neuroimaging Evidence for Visual Character Processing

Evidence from neuroimaging studies supports the aforementioned dissociation. Although there is considerable overlap between the activation patterns during reading of English and Chinese language, research has shown unique activation for Chinese character processing in the left lateral middle frontal cortex (Tan et al., 2001; Lesch & Pollatsek, 1998). Not surprisingly, this region has been associated with visuospatial processing and visual working memory (Courtney, Petit, Maisog, Ungerleider, & Haxby, 1998). Importantly, areas associated with memory for visuospatial information such as the right frontal pole (BA10/11), frontal operculum (BA 47/45), dorsolateral frontal gyrus (BA 9/44), and the superior and inferior parietal lobules (BAs 7, 40/39) [13,p. 841], are all strongly implicated in Chinese, but not in English reading (Tan et al., 2001). Similar networks were also recruited when participants were making fine visuo-spatial discriminations between orthographically legal and illegal characters (Dong et al., 2005). Together, these results suggest that processing of Chinese characters requires a uniquely visuo-spatial aspect that is not apparent in English word processing.

2.1 Experiment 1

I have presented some evidence to indicate that processing of the Chinese language has a relatively stronger visuospatial processing aspect than processing of the English language, which relies more on phonology. The current study, conducted in collaboration with Dr. Janet Hsiao at Hong Kong University (Fernandes, Wammes, & Hsiao, 2013) was designed to probe representations in memory by taking advantage of individual differences in how participants are able to encode and store information. Such differences should influence the manner in which these stimuli are processed, thereby influencing susceptibility to memory interference from different distracting tasks. The comparison between retrieval of logographic and alphabetic languages was accomplished by measuring memory for verbal information across English monolinguals and Chinese-English bilinguals. Bilinguals studied words written in simplified Chinese characters, whereas English monolinguals studied English words. Memory for these items was measured with a recognition task under conditions of either full attention (FA) or two different dual-task divided attention (DA) conditions, differing in their reliance on phonological vs visuo-spatial processing requirements. I hypothesized that the Chinese group would be much more susceptible to interference from the visuo-spatial distracting task, as a result of their strong reliance on spatial processing for Chinese characters. I predicted the opposite pattern in the English monolinguals, such that they would be much more susceptible to interference from the phonological distracting task.

2.1.1 Method

Participants

Participants were 36 English speaking undergraduate students (19 male) from the University of Waterloo, whose ages ranged from 18 - 24 years (*M* = 20.22, *SD* = 1.49). These were secondary data collected from Fernandes and Guild (2009), to serve as my monolingual English group. My bilingual Chinese-English group was composed of 24 participants who were bilingual Mandarin-English undergraduates from Mainland China attending the University of Hong Kong, ranging in age from 18 to 24 years (*M* = 20.33, *SD* = 1.63), with education ranging from 13-19 years (*M* = 14.81, *SD* = 1.77). To qualify, participants in this group were required to successfully complete a basic reading test to indicate their ability to parse both meaning (*M* = 99.2%, *SD* = 1.6%) and pronunciation (*M* = 99.6%, *SD* = 1.0%) from Chinese characters.

Materials

Chinese character memory task. The stimuli for the memory task were composed of 70 single characters, each written in their corresponding simplified Chinese character. Characters had a frequency between 2 and 5,921 per 662,700 occurrences and a mean number of 8.24 strokes (Ho, 1998). These were divided into a single practice list of 10 characters, as well as 3 experimental lists of 20 characters each. Within each list, half of the characters were randomly chosen to be targets, whereas the other half were used as lures on the recognition test. Characters appeared approximately 6 cm high and 8 cm wide on a computer screen (See Figure 1 for procedure with sample characters).

English word memory task. The word stimuli for the memory task in Fernandes and Guild (2009)) were composed of 112 nouns, each written in English letters. Words had a frequency between 40 and 100 per million and a mean word length of 5.84, based on the Frequency Analysis of English Usage (Francis & Kucera, 1982). These were divided into a single practice list of 16 words, as well as 3 experimental lists of 32 words each. Within each list, half of the words were randomly chosen to be targets, whereas the other half were used as lures.

Distracting tasks. The same stimuli were used for both the phonological and visuospatial distracting tasks, and consisted of 23 of the 26 letters of the English alphabet (omitting A, M, and W). These were recorded by a female speaker as separate audio files (.wav) via a microphone using Sound- Designer II software (Palo Alto, CA). Audio files were created such that the onset of the letter was at the beginning, but followed by silence, such that each .wav file was approximately 1500 ms in duration.

Procedure

Participants were seated in front of a computer monitor, and the experiment was administered using E-prime v1.1 software (Psychology Software Tools Inc., Pittsburgh, PA) via an IBM computer. Instructions were presented in English on the screen, as well as read aloud by the experimenter. The session began with a practice phase to familiarize participants with the tasks, followed by completion of the experiment. I will begin by detailing the individual tasks then, in the Experimental section, I will outline the manner in which they were completed.

Primary recognition task. Depending on their language group, participants were asked to study either 10 Chinese characters or 16 English words for later recognition. Groups studied different quantities of stimuli, because pilot testing suggested that performance was poor when the number of to-be-remembered Chinese characters was higher, and in previous research similar issues with large sets of visuo-spatial grids (Fernandes & Guild, 2009) . Stimuli were presented one at a time in the center of the screen for 3500 milliseconds, followed by a fixation cross for 500 milliseconds. After a brief delay, participants were subsequently instructed to complete the recognition task. This consisted of pressing the “m” key to identify stimuli they remembered seeing in the study phase, while refraining from pressing the “m” key if they did not remember the stimulus. The characters or words from study were presented intermixed randomly among an equal number of lure characters or words. Each stimulus was presented in the center of the screen for 1500 ms, during which time the participants were required to make their response. The stimulus was not terminated by the participant’s response, but remained until 1500 ms had elapsed. Between stimuli, a fixation cross was presented for 500 milliseconds (see Figure 1).

Phonological distracting task. Participants heard a female voice speaking a list of 20 randomly selected letters aloud. Each letter was presented as an audio file was played for 1,500 milliseconds in duration followed by 500 milliseconds of silence. Participants had to judge whether the presented letter rhymed with the long “e” vowel. Participants were asked to make a “yes” or “no” response immediately after presentation of each letter, and the experimenter recorded their responses. For example, letters requiring a “yes” response are B, C, D, E, G, P, T, and V. If the letter did not rhyme with the long “e” vowel, the participant responded “no.” Thus, the task required the participant to make phonological decisions about the letters they heard. For the Chinese-English bilingual group, 8 letters requiring a “yes” response were randomly selected, and presented randomly among 12 randomly selected letters requiring a “no” response. For the English group, 12 letters requiring a “yes” response were randomly selected, and presented randomly amongst 20 randomly selected letters requiring a “no” response. While there are different numbers of “yes” and “no” responses between language groups, the ratio was roughly preserved. Each group completed a differential number of letter trials to match the number of recognition trials the participant completed.

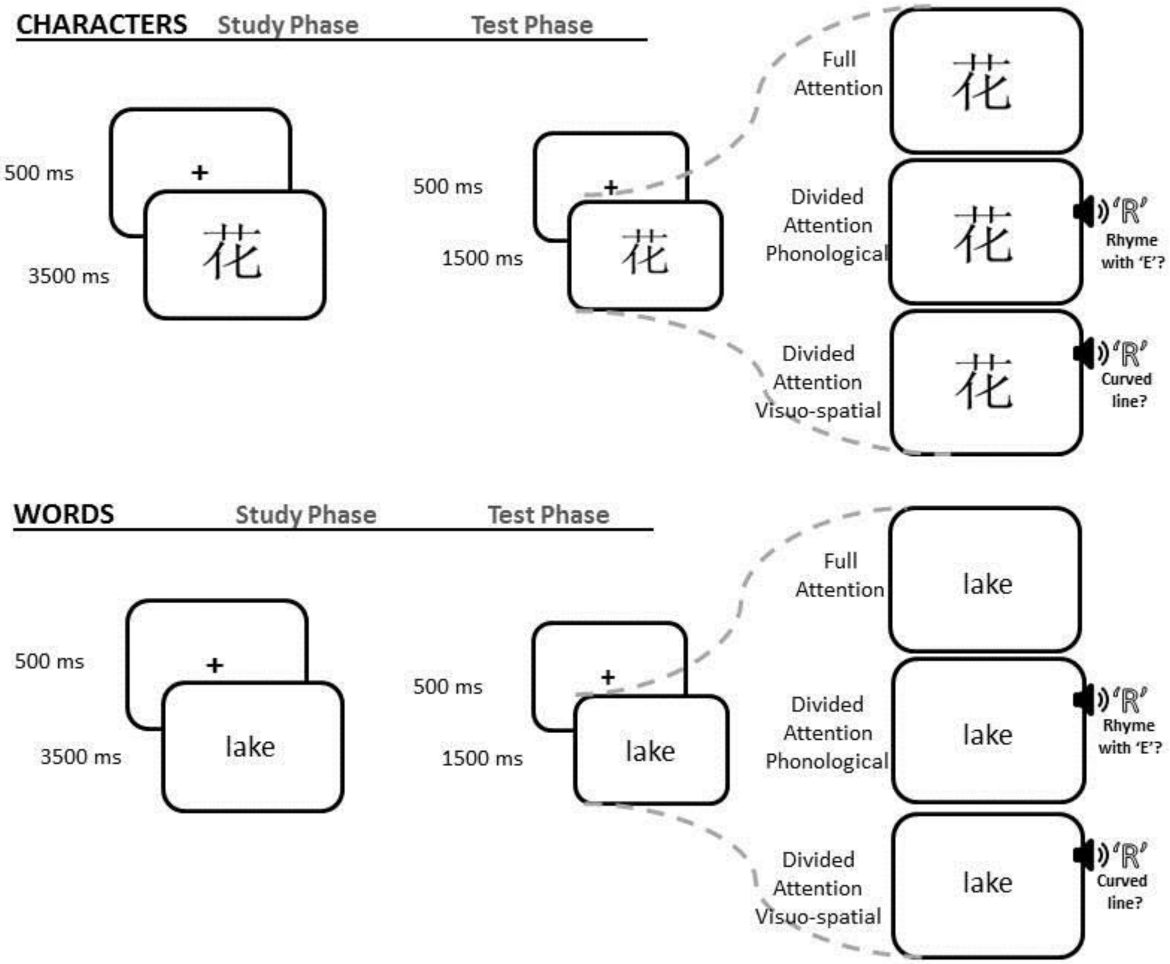

Figure 1. Sample trials for the recognition task of Chinese characters or English words under full attention (FA) or concurrently with a distracting task requiring either phonological (DAP) or visuo-spatial (DAV) processing.

Visuospatial distracting task. This task differed from the phonological distracter only in the judgment that participants were required to make. They were asked to imagine the letter in their "mind's eye," and to respond "yes" if the letter contained a curved line when in its capitalized form. Participants were instructed to think of the capitalized alphabet. Correct "yes" responses would be to the letters B, C, D, G, P, J, O, P, Q, R, S, and U. If the letter, when capitalized, did not contain a curved line, the participant responded “no.” The experimenter referred to the letters on the computer keyboard to illustrate how participants should visualize the individual letters, and told participants to base their curved/not curved decisions on these templates.

Experimental phase. After a short practice phase used to familiarize participants with the tasks, a baseline measure of one of the distracting tasks was completed. Next, the three memory conditions were completed, and lastly a baseline of the other distracter was done. The order of the baselines was counterbalanced across participants, as was the order in which the memory conditions were completed. The baselines consisted of the phonological or the visuospatial distracting task described above, on their own.

For each of the memory conditions, encoding during the study phase was performed under full attention; what differed between conditions was how recognition was completed. In the FA condition, recognition was performed alone. In the divided attention phonological (DAP) and divided attention visuo-spatial (DAV) conditions, participants had to make their recognition decisions to the simplified Chinese characters while simultaneously making decisions to letters according to the corresponding distracting task (the phonological distracting task for DAP; the visuo-spatial for DAV). The onset of the first item in the visually presented recognition task and the auditorily presented distracting task was simultaneous. Participants were told to devote equal effort to performing the memory and distracting task. A short break of 1 to 2 minutes was inserted after each recognition condition.

2.1.2 Results

Recognition accuracy. Memory performance (calculated as hit rate minus false alarm rate) was the dependent variable. Memory was for English words in the Fernandes and Guild (2009) group and for Chinese characters in the Chinese-English group described earlier. A repeated measures ANOVA was conducted with Group (Chinese-English, English-only) as the between- and Condition (FA, DAP, DAV) as the within-participant factor. Mauchly's test was not significant, so sphericity was assumed. There were significant main effects both of Condition, F (2, 116) = 40.86, p < .001, and of Group, F (1, 58) = 12.43, p < .01. Here the Group X Condition interaction was significant, F (2, 116) = 4.68, p < .05 (See Figure 2).

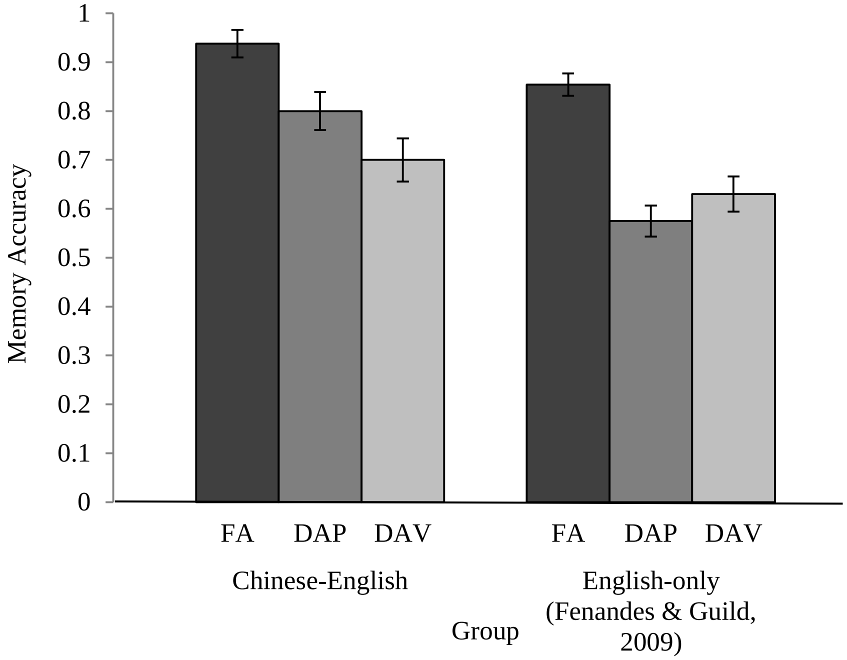

Figure 2. Experiment 1: Mean recognition accuracy for Chinese-English participants remembering Chinese characters and English-only participants remembering English words in each attention condition, under FA = full attention, DAP = divided attention phonological, and DAV = divided attention visuo-spatial retrieval conditions.

Planned comparisons indicated that for both groups there was a significant main effect of Condition (Chinese-English group: F (2, 46) = 13.96, p < .001; English group from Fernandes and Guild [1]: F (2, 70) = 36.18, p < .001). For the Chinese-English group, the main effect of

Condition was driven by accuracy being higher in the FA than in both the DAP, *F* (1, 23) = 10.91, *p* < .01, and DAV, *F* (1, 23) = 26.03, *p* < .01 conditions. Notably, accuracy was significantly lower in the DAV condition than in the DAP condition in this group, *F* (1, 23) = 4.525, *p* < .05.

The accuracy differences in the English group from Fernandes and Guild revealed different results. The main effect of Condition was characterized by poorer performance in both DA conditions relative to FA (DAP: F (1, 35) = 67.57, p < .001; DAV: F (1, 35) = 50.13, p < .001); accuracy in the DAP was numerically lower than in the DAV condition, although not reliably so, F (1, 35) = 2.09, p = .16 (See Table 1).

Table 1

Mean Recognition Accuracy in the Chinese-English Group Retrieving Chinese Characters, and in the English-only Group Retrieving English Words (from Fernandes & Guild 2009), in Each Attention Condition (Standard Errors in Parentheses)

	Memory Condition		
Language Group	Full Attention	DA Phonological	DA Visuo-spatial
Chinese-English	0.93 (0.02)	0.80 (0.04)	0.70 (0.04)
English-only	0.85 (0.02)	0.58 (0.03)	0.63 (0.04)

Distracting task. Data were analyzed using a repeated measures ANOVA in a 2 X 2 X 2 ANOVA with Group (Chinese-English bilingual, English) as a between-participants factor and Attention (full, divided), as well as Distractor Task (phonological, visuo-spatial), as within-participant factors. The main effect of Group was non-significant, F (1, 58) = 0.59, p >.05. There was a significant main effect of Attention, F (1, 58) = 22.20, p < .001, such that performance was better overall under FA than DA conditions, but no main effect of Distracting Task, F (1, 58) = 0.86, p > .05. There were several 2-way interactions: Group X Distracting Task, F (1, 58) = 5.71,

$p < .05$, Group X Attention, $F(1, 58) = 17.54$, $p < .001$, Distracting Task X Attention, $F(1, 58) = 5.83$, $p < .05$, and a significant 3-way interaction of Group X Distracting Task X Attention, $F(1, 58) = 11.32$, $p < .01$.

For the Chinese-English group, there was no main effect of Distracting Task, $F(1, 23) = 0.69$, $p > .05$, or Attention, $F(1, 23) = 0.10$, $p > .05$, although the Distracting Task X Attention interaction was present, $F(1, 23) = 15.07$, $p < .01$. The Distracting Task X Attention interaction was characterized by a larger reduction in performance, from FA levels, on the phonological distracting task than on the visuospatial distracting task. Conversely, for the English group, there was a main effect of Distracting Task, $F(1, 35) = 8.57$, $p < .01$, with a larger reduction in performance on the visuo-spatial task than phonological task. There was also a main effect of Attention, $F(1, 35) = 55.32$, $p < .001$, with better performance under full attention than under dual-task conditions, although again the Distracting Task X Attention interaction was not significant, $F(1, 35) = 0.54$, $p > .05$ (see Table 2 for means).

Table 2

Mean Distracting Task Performance in Chinese-English Bilinguals and in an English-only Monolingual Group (from Fernandes & Guild, 2009) in Each Attention and Task Condition (Standard Errors in Parentheses)

	Baseline		Divided Attention	
Language Group	Phonological	Visuo-spatial	Phonological	Visuo-spatial
Chinese-English	0.94 (0.01)	0.96 (0.01)	0.98 (0.01)	0.92 (0.02)
English-only	0.96 (0.01)	0.99 (0.00)	0.88 (0.02)	0.93 (0.01)

2.1.3 Discussion

I measured recognition memory in bilingual Chinese-English and monolingual English speakers. Participants were visually presented with simplified Chinese characters, under full attention, and later asked to recognize them while simultaneously engaging in distracting tasks that required either phonological or visuo-spatial processing of auditorily presented letters. Chinese speakers showed significantly greater memory interference from the visuo-spatial than from the phonological distracting task, a pattern that was not present in the English group. This difference suggests that retrieval of simplified Chinese characters differentially requires visuo-spatial processing resources in Chinese speakers; these are compromised under dual-task conditions when such resources are otherwise engaged in a distracting task. Critically, I showed the complementary pattern, albeit nonsignificantly, in a group of English speakers, whose memory for English words was disrupted to a greater degree from the phonological than from the visuo-spatial distracting task. In line with the aforementioned study (Fernandes & Guild, 2009), the current results suggest that when two simultaneously completed tasks require similar processing resources, competition for these limited resources results in detrimental effects of DA at retrieval. Importantly, my results display that even within verbal materials, the patterns of interference can be quite divergent, depending on how one has learned to process the information.

It is important to note that there was a significant main effect of language Group, such that the English speakers performed significantly worse overall than the Chinese speakers. This can be explained by the imbalance in the number of to-be-remembered stimuli between the groups, a potential limitation of this experiment. Pilot testing had indicated that accuracy was low when larger lists of characters were encoded, so the list lengths were offset. While this should be addressed in future research, my interest was not in overall performance differences between groups, but in the crossover interaction which was contingent on processing requirements. As such, the main effect does not invalidate the dissociation uncovered here.

As reviewed in the introduction to this chapter, the Chinese and English languages both require aspects of phonological and visuospatial processing, although there are differences in the relative importance of each for the two languages. Specifically, English appears to require more phonological processing whereas Chinese appears to require more visuospatial processing. The interaction of group status by memory condition in this study provides direct support to this notion, while also showing that retrieval suffers processing-specific interference across diverse verbal materials, though the effect in the English group was not significant.

Chinese characters, although they are verbal stimuli, require extensive visuospatial processing. But because they are verbal in nature, I was still unable to draw conclusions about whether processing-specific interference occurs in stimulus sets outside of the verbal domain, limiting generalizability. Specifically, the question remains whether processing-specific interference is applicable to a true visuo-spatial stimulus with no phonological or semantic content. With this in mind, my next set of studies examined memory for faces, a more common and ubiquitous visuo-spatial stimulus. Using faces allowed us to test whether a processing-specific account of episodic retrieval interference resulting from DA conditions was generalizable.

Chapter 3: Interfering with Memory for Faces

Most of the aforementioned studies examined memory for words or other verbal materials. The current chapter aims to address whether a processing-specific account of memory interference is generalizable to visuo-spatial stimuli. Additionally, all of the studies reviewed thus far, including my own, examined memory interference effects at retrieval when the distracting tasks were presented in a different modality (auditorily) than the primary memory task (visually). To my knowledge, examination of the effect of DA at retrieval with concurrent tasks presented within the same modality has not been examined, except in the case of structural interference (Armstrong, 1993; Kahneman, 1973). Previous work has avoided such conditions due to input interference between tasks. Arguably the best method of testing a processing account, however, would be to compare interference patterns between DA conditions in which both distracting tasks are *within* the same modality as the target task, but differ in terms of the whether processing requirements of the distracting tasks do or do not overlap with the target memory task. Thus, the differing distracting task conditions should produce similar levels of structural interference, but differential patterns of additional processing interference depending on the processing overlap between tasks.

The current research sought to compare the effect of two different, simultaneously performed visual tasks, on memory for faces. Faces provide an ideal sample of a visuo-spatial stimulus to test my hypothesis, as they can be processed in two different but related ways, configurally or featurally (Goffaux & Rossion, 2006, Rhodes, 1988). Determination of interrelations and spacing between facial features requires configural processing, whereas detection of the stand-alone features themselves engages featural processing (Cabeza & Kato, 2000; Van Belle, De Graef, Verfaillie, Busigny, & Rossion, 2010). Although these processes are not entirely dissociable, there is substantial evidence from neuroimaging (Arcurio, Gold, & James, 2000; Coin & Tiberghien, 1997; Nichols, Betts, & Wilson, 2010) and neuropathology (Barense, Henson, Lee, & Graham, 2010) studies to indicate that different configural and featural processing streams exist at the level of the brain.

In the current research I chose to examine memory for target faces because there is a strong literature suggesting that these visuo-spatial stimuli are processed primarily configurally, and that memory for an upright face relies largely on configural or holistic processing (Tanaka & Farah, 1991; 1993; Farah, Wilson, Drain, & Tanaka, 1998). This claim is strengthened by the fact that memory for an individual feature is substantially weakened when the configuration is rearranged (Murray, 2004), indicating that in an upright face configural supersedes featural processing. As such, although featural processing plays a role in face memory, retrieval is likely much more reliant on configural processing.

It was the aim of the current research to determine whether episodic retrieval of studied faces would suffer to a greater extent from a distracting task that also engaged the same type of processing. The finding of selective configural interference on tasks involving faces is quite novel (Palermo & Rhodes, 2002). It has thus far only been examined in short-term or working memory tasks involving whole-part distinctions; interference with episodic memory for faces remains untested. For example, previous research has shown that there is a limit to one's face processing ability, as peripheral presentation of distracting faces can interfere with face-related task performance (Cheung & Gauthier, 2010; Gonzalez-Garrido, Ramos-Loyo, Gomez-Velazquez, Alvelais Alarcón, & Moises de la Serna Tuya, 2007; Palermo & Rhodes, 2002; Pezdek, O'Brien, & Wasson, 2001). In Cheung and Gautier's (2010) study, when participants had to maintain a working memory load of three faces prior to a face matching task, their performance was much worse than when there was no load. Similarly, when a similar face-matching task was performed while simultaneously performing a task based on peripheral flanker faces, performance also suffered (Palermo & Rhodes, 2002). In another experiment within their 2010 study, Cheung and Gauthier (2010) used a composite task to show a decrease in congruency effects when participants' working memory was loaded with face stimuli. Congruency effects in this case refer to the benefit in performance that occurs when the bottom halves of two consecutively presented faces are the same, on a task in which participants are instructed to pay attention to, and match, only the top halves. Here, performance benefits are indicative of configural processing (Farah et al., 1998). Therefore a reduction of congruency effects indicates that configural processing is susceptible to interference from additional faces (Cheung & Gauthier, 2010). I predicted, similar to findings with short-term memory / working memory for faces (Kemps & Tiggeman, 2007), that selective interference would occur for episodic memory of faces, primarily when a distracting task also required configural processing. In other words, there will be interference simply due to the fact that both tasks involve face stimuli, but additional interference will be incurred due to the competition for configural processing as well.

It is difficult to fully separate configural and featural processing (Bartlett, Searcy, & Abdi, 2003; McKone, Martini, & Nakayama, 2003), especially without drastically altering the appearance of a face. Accordingly, to differentiate configural and featural processing, I designed distracting tasks that could bias participants toward one type of processing or the other, and that measured the interference that each produced on episodic memory for a set of faces. In Experiment 2, I tested whether a distracting task requiring configural processing of faces would interfere with face recognition memory more than one requiring featural processing. In

Experiment 3, I compared the pattern of memory interference when target faces were presented in an upright (configurally processed) or inverted (featurally processed) orientation. I predicted a crossover interaction, such that memory for configurally represented (upright faces) would be compromised more by a configural than a featural distracting task, whereas memory for featurally represented (inverted) faces would display the opposite pattern.

3.1 Experiment 2

The goal of Experiment 2 was to determine first whether face memory was susceptible to dual-task interference at retrieval, and second, whether this interference occurred differentially as overlap in processing requirements increased. Upright faces are largely processed, and likely retrieved, configurally (Farah et al., 1998). Two distracting tasks were crafted such that one required configural and the other featural processing. It was expected that both tasks would result in substantial costs to face memory performance but that concurrently performing the configural task would interfere with memory performance to a greater degree than would performing the featural one.

3.1.1 Method

Participants. Twenty-four undergraduate students (14 female) at the University of Waterloo took part in the experiment. They ranged in age from 18 to 44 (*M* = 21.25, *SD* = 5.16), with between 13 and 27 years of education (*M* = 15.54, *SD* = 2.83). The experiment was completed either for course credit or monetary remuneration. All participants had normal or corrected to normal vision, and learned English before the age of seven.

Materials. Faces were taken from the Glasgow Unfamiliar Face Database (GUFD; Burton, White, & McNeill, 2010). Faces were selected such that none had visible jewelry, facial hair, or abnormal/distinctive features that could be used as cues (See Figure 3). The remaining stimuli consisted of 240 Caucasian faces, split equally by gender. All faces were resized such that every image file was identical in length (4.5 inches), and width (3.5 inches).

Figure 3. Sample face stimuli for the target memory and distracting tasks in Experiment 2.

Face memory task. Faces were randomly assigned to three separate lists of 30 and acted as stimuli for the recognition memory task. Within these lists, 15 faces were randomly selected to be lures and 15 to be targets. The remaining 30 faces were preserved for use in the practice phase of the experiment. Within each set of 30, there was an equal gender distribution. Within the sets of 15 targets or lures, either 7 or 8 faces were male. This gender imbalance was counterbalanced across participants. A set of extraneous faces from the original set were blurred beyond recognition, to be used as ‘fillers’ during the FA memory condition.

Distracting tasks. For my featural distracting task, 60 faces were selected such that half had light-colored eyes and half dark-colored eyes. For my configural distracting task, it was critical that half of the faces have their nose positioned closer to their eyes and half closer to their mouth. To meet this criterion, 60 of the faces were altered slightly using the GNU Image Manipulation Program (GIMP 2). Specifically, in a randomly selected subset of 60 of the faces, regions above and below the nose were subtly stretched or compressed.

Procedure. Stimulus presentation and response collection was controlled using E-prime v2.0 software (Psychology Software Tools Inc., Pittsburgh, PA) via an IBM computer. Instructions were presented in English both on-screen and were also read aloud by the experimenter. A practice phase was completed first, to familiarize participants with the tasks, followed by the full experiment. As before, I begin by detailing the tasks, and then describe how they were completed and combined in the experimental section. The faces for each task are presented with a black bar either above or below the image, to indicate which task was to be performed.

Primary recognition task. During each of the three encoding phases, participants were asked to study 15 pictures of faces for a later memory test. Faces were centrally presented one at a time for 3000 ms, preceded by a fixation cross for 500 ms. After a brief delay, participants completed the recognition task. During each of the three retrieval phases, participants were shown 30 faces (15 ‘targets’ and 15 ‘lures’), each with a black bar above it. Each trial began with a 500 ms fixation, followed by the face for 2000 ms and a blank screen for 500 ms. Participants were instructed to press the “m” key if they recognized the face and to refrain from responding if they did not recognize the face (see Figure 4 for similar design).

Featural distracting task. After a 500 ms fixation, faces were centrally presented, one at a time, with a black bar underneath each. These were presented for 2000 ms, followed by a blank screen for 500 ms. Participants were asked to answer the following question for each face trial: “Does the face have light eyes?” If the face had light eyes, participants were instructed to respond “yes.” If the face did not have light eyes, participants were to respond “no.”

Configural distracting task. This task only differed in the question that participants were asked to answer: “Is the nose closer to the eyes than the mouth?” If the nose was closer to the eyes, participants were to respond “yes,” whereas if the nose was closer to the mouth, they were to respond “no.”

Experimental Phase. After completing a practice phase, participants completed a baseline measure of one of the distracting tasks (either featural or configural), as described above. Following this, the three memory conditions were completed. The session ended with a baseline of the remaining distracting task, as described above. Order of tasks was completely counterbalanced.

The encoding phase for each of the three memory blocks was completed under full attention. Following this, participants performed the retrieval stage of the recognition memory task either under full attention (FA), where recognition was performed alone, or under one of two DA conditions. The divided attention featural (DAF) block required completion of recognition concurrently with the featural distracting task, whereas the divided attention configural block (DAC) required simultaneous completion of the configural distracting task. The onset of the stimuli for each task was simultaneous. For the DA conditions, participants were explicitly told that each task was equally important and to divide their attention equally between them.

Because stimuli for both tasks are presented visually in the DA conditions, a peripheral cue was required to indicate which face belonged to the respective tasks. Participants were presented two faces presented side by side, one with a black bar above and one with a black bar below. The location of the bar indicated the task to be performed (either memory or distracting task). The location of the face (left or right) for each concurrent task switched randomly on each trial to prevent the participant from developing a strategy of always performing one task first.

3.1.2 Results

Recognition accuracy. Memory accuracy (calculated as hit rate – false alarm rate) was calculated for each participant, and served as the dependent variable. Data were analyzed using repeated measures ANOVA, with Attention (FA, DAF and DAC) as a within-participant factor. Mauchly's test of Sphericity was non-significant, X^2 (2) = 2.40, *p* = .30, so equal variances were assumed. There was a significant main effect of Attention, *F* (2, 46) = 13.89, *MSE* = .034, *p* < .001, $\eta^2 = .38$

Simple effects analyses indicated that this effect was driven by accuracy in the FA condition being higher than that in either the DAF, *F* (1, 23) = 35.09, *MSE* = .050, *p* < .001, $\eta^2 = .60$, or DAC, *F* (1, 23) = 14.34, *MSE* = .065, *p* < .005, $\eta^2 = .38$, condition; there was no difference between the DAF and DAC conditions, *F* (1, 23) = 1.44, *MSE* = .087, *p* > .05, $\eta^2 = .06$, *ns* (See Table 3). Thus, memory for a visuo-spatial stimulus, specifically an image of a face, can be interrupted by distracting tasks involving similar stimuli (i.e. faces). Results did not, however, show the hypothesized processing-specific dissociation between the DAF and DAC conditions.

Table 3

Experiment 2: Mean Recognition Accuracy During the Memory Task For Faces in Each Attention Condition (Standard Errors in Parentheses)

	Attention Condition		
	Full Attention	DA Featural	DA Configural
Accuracy	.71(.04)	.44(.05)	.51(.05)

Distracting task performance. Distracting task performance was measured as the proportion of the 30 trials that were responded to correctly. A 2 x 2 repeated measures ANOVA was conducted, with Attention (Baseline, DA) and Task (Featural, Configural) as within-participant manipulations. Results revealed significant main effects both of Attention, *F* (1, 23) =

27.34, $p < .001$, and of Task, $F(1, 23) = 39.88$, $p < .001$, as well as a significant interaction between Attention and Task, $F(1, 23) = 10.88$, $p < .005$. Paired samples t-tests indicated that in both Baseline, $t(23) = 7.86$, $SE = .020$, $p < .001$, and DA, $t(23) = 3.67$, $SE = .020$, $p < .005$, performance was lower on the Featural task (Baseline: $M = .88$, $SE = 0.06$; DA: $M = .83$, $SE = 0.08$) than on the Configural task (Baseline: $M = .98$, $SE = 0.02$, DA: $M = .89$, $SE = 0.09$). Additionally, both the Featural, $t(23) = 3.60$, $SE = .020$, $p < .005$, and the Configural, $t(23) = 5.56$, $SE = .020$, $p < .001$, task were performed worse under DA than under Baseline. These results show that the interaction was driven by the effect of Task being larger in Baseline than DA. In other words, performance in the configural task was superior to the featural task, however this advantage was larger in the baseline condition.

3.1.3 Discussion

I found significant interference with memory accuracy in both DA conditions relative to the FA condition, in line with the material-specific account of memory interference effects posited by Fernandes and Moscovitch (2000). I had predicted differential interference based on the type of processing required of the distracting task (as per Fernandes & Guild, 2009; Fernandes et al., 2013). I reasoned that because upright faces primarily engage configural processing (Farah et al., 1998; Richler, Mack, Gauthier, & Palmeri, 2009), a distracting task emphasizing configural as opposed to featural processing would interfere more with memory for faces. My hypothesis was not supported. This might have occurred because the featural distracting task also engaged configural processing because the faces were upright. That is, although the featural distracting task required responses based on eye color, biasing processing to be featural, they were also presented in the upright position, engaging configural processing. As a result, the distracting tasks in Experiment 2 may not have adequately captured the distinction between configural and featural processing. To better isolate featural processing in Experiment 3, I modified the featural task: Distracting task faces in the DAF condition were rotated 180 degrees to offset configural processing and create a more featurally driven task (Yin, 1969).

3.2 Experiment 3

Experiment 2 showed evidence consistent with a material-specific account, but failed to show a processing-specific pattern of memory interference. It is likely, however, that my featural distracting task also engaged configural processing as faces were presented upright. It is well supported that upright faces are primarily processed configurally (Farah et al., 1998), whereas inverted faces are processed more featurally (Yin, 1969). In Experiment 3, to better isolate featural processing in the DAF condition, distracting faces were inverted.

Additionally, I also sought a crossover interaction by comparing the pattern of memory interference when target faces were studied and tested in the upright or inverted position. The data would support the processing-specific account of interference if I could show that memory for upright faces was worse in the DAC than in the DAF condition, whereas the reverse was true for memory of inverted target faces. Accordingly, the aim for Experiment 3 was to examine the influence of simultaneously performed distracting tasks on memory for both upright and inverted faces.

To bias participants toward featural processing, distracting task faces in the DAF condition were inverted, and distracting faces in the DAC condition were low-pass filtered (Goffaux & Rossion, 2006). It was predicted that due to its relative reliance on configural processing, memory for upright faces would be subject to greater interference from my configural than from my featural distracting task. Memory for inverted faces, however, should display the reverse pattern, given its reliance on featural processing.

3.2.1 Method

Participants. Forty-eight naïve undergraduate students (26 female) at the University of Waterloo completed the experiment. Their ages ranged from 19 to 25 (*M* = 20.81, *SD* = 1.44), with between 12 and 18 years of education (*M* = 15.16, *SD* = 1.44). The experiment was completed either for course credit or monetary remuneration. All participants had normal or corrected to normal vision, and learned English before the age of 7.

Materials. The stimuli used for this experiment were identical to those of Experiment 2, except for two key differences in the stimuli selected for the featural task. First, results from distracting task performance in Experiment 2 indicated that the featural was performed slightly worse than the configural distracting task. Item analysis, however, showed that these effects were primarily driven by a high frequency of incorrect responses for a smaller subset of items. Further inspection of these items indicated that they may have been too ambiguous for a dichotomous decision. As such, 11 of the 60 were replaced with less ambiguous faces, as determined by pilot testing for Experiment 3.

Further, all stimuli for the featural distracting task were inverted using ImageMagick software (ImageMagick Studio LLC, 1999-2013).

Procedure. Participants were randomly assigned to either the Upright or the Inverted condition. For those in the Upright condition, faces used for the recognition memory task were presented in the upright position. The procedure was identical to that of Experiment 2 (see Figure 4), except that distracting faces in the featural distracting task condition were inverted. For those in the Inverted condition, faces used for the recognition memory task were also presented in the inverted position, to bias the recognition task towards featural processing. In addition, a low pass filter was applied to the distracting faces used in the DAC condition as others have suggested that this biases participants more toward configural processing (Goffaux & Rossion, 2006).

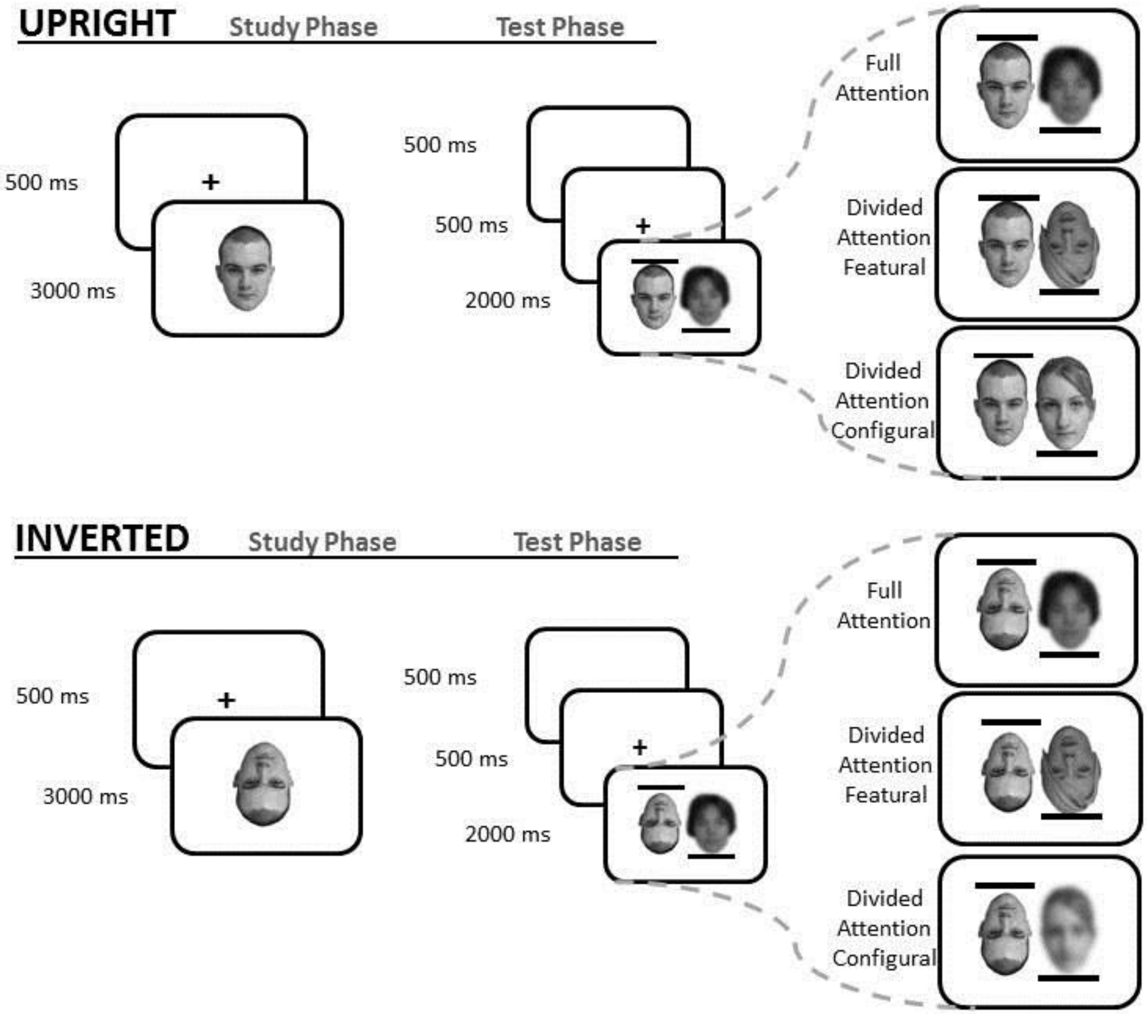

Figure 4. Sample trials for recognition of Upright or Inverted faces under full attention (FA) or concurrently with a distracting task requiring either featural (DAF) or configural (DAC) processing.

3.2.2 Results

Recognition accuracy. A repeated measures ANOVA was conducted. Face Group (Upright or Inverted) was included as the between-participants factor, and Attention condition (FA, DAF or DAC) was included as the within-participant factor. Mauchly's test of Sphericity was non-significant, $X^2(2) = 0.58$, $p = .75$, thus equal variances were assumed. Repeated measures ANOVA showed a significant main effect of Face Group, $F\ (1, 46) = 588.92$, $MSE = .076$, $p < .001$, $\eta^2 = .93$, such that accuracy was higher for Upright than for Inverted faces. There was also a significant main effect of Attention, $F\ (2, 92) = 30.37$, $MSE = .028$, $p < .001$, $\eta^2 = .40$, and a significant Attention X Face Group interaction, $F\ (2, 92) = 9.35$, $MSE = .028$, $p < .001$, $\eta^2 = .17$. (See Table 4 for means)

Table 4

Experiment 3: Mean Recognition Accuracy During the Memory Task For Upright vs Inverted Faces in Each Attention Condition (Standard Errors in Parentheses)

	Attention Condition		
Face Type	Full Attention	DA Featural	DA Configural
Upright	.81(.03)	.65(.04)	.45(.05)
Inverted	.61(.03)	.37(.05)	.46(.04)

To determine the source of the interaction, separate repeated measures ANOVAs were conducted for each Face type (Upright and Inverted). For Upright faces, Mauchly's test of Sphericity was non-significant, $X^2(2) = .28$, $p = .87$, so equal variances were assumed. Again there were no effects or interactions with Order, so the analysis was performed without Order as a factor. There was a significant main effect of Attention, $F\ (2, 46) = 29.13$, $MSE = .026$, $p < .001$, $\eta^2 = .56$. Specifically, memory accuracy in the FA condition was significantly higher than in both the DAF, $F\ (1, 23) = 12.15$, $MSE = .048$, $p < .005$, $\eta^2 = .35$, and DAC, $F\ (1, 23) = 52.45$, $MSE = .058$, $p < .001$, $\eta^2 = .70$, conditions (See Table 4). Crucially, results showed that memory accuracy was significantly lower in the DAC than in the DAF condition, $F\ (1, 23) = 18.68$, MSE

= .051, $p < .001$, $\eta^2 = .45$, indicating that, for Upright faces, the configural task interfered significantly more with memory accuracy than did the featural distracting task (See Figure 5).

For Inverted faces, Mauchly's test of Sphericity was also non-significant, $X^2(2) = .21$, $p =$ .34, so equal variances were assumed. Again there were no effects or interactions with Order, so the analysis was performed without Order as a factor. There was again a significant main effect of Attention, $F\ (2, 46) = 11.85$, $MSE = .030$, $p < .001$, $\eta^2 = .34$. Similar to Upright faces, memory for Inverted faces was significantly higher in the FA condition than in both the DAF, $F\ (1, 23) =$ 18.15, $MSE = .077$, $p < .001$, $\eta^2 = .44$, and DAC, $F\ (1, 23) = 12.34$, $MSE = .045$, $p < .005$, $\eta^2 = .35$, conditions (See Table 4). Opposite to the findings with upright faces, results showed that memory was lower in the DAF than in the DAC condition, $F\ (1, 23) = 3.21$, $MSE = .059$, $p =$ .086, $\eta^2 = .12$. Alhough this effect only approached significance, it suggests that, for Inverted faces, the featural distracting task in the DAF condition interfered more with memory accuracy than did the configural distracting task in DAC (see Figure 5). The finding of a significant Attention X Face Group interaction is thus driven by the opposite pattern of accuracy results in the DA conditions for upright compared to inverted faces.

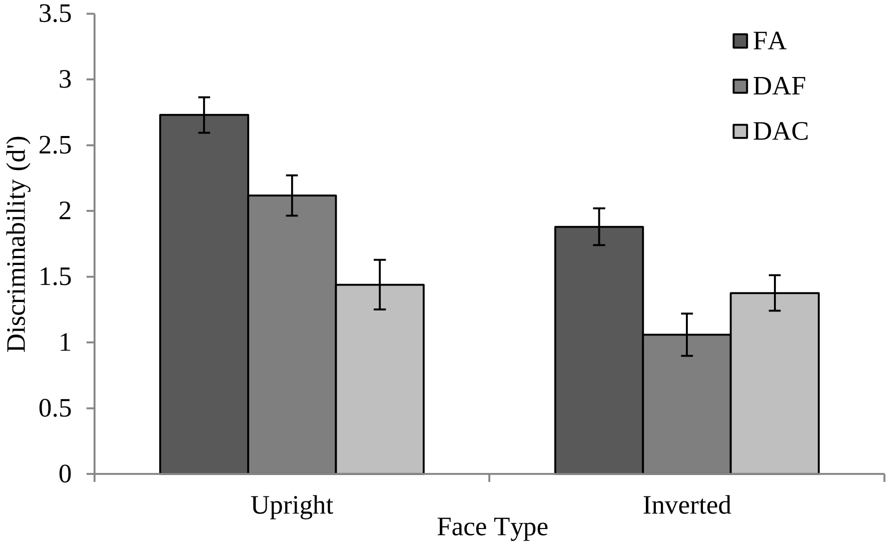

Figure 5. Memory discriminability for Upright vs Inverted faces under full attention (FA) or concurrently with a distracting task requiring either featural (DAF) or configural (DAC) processing. Error bars represent standard error.

Distracting task performance. Data for the distracting task were analyzed similarly to Experiment 2. Again, task performance was computed as the proportion of correct responses. A 2 x 2 x 2 repeated measures ANOVA was conducted, with Face Group as a between-participants variable, and Attention (Baseline, DA) and Task (Featural, Configural) as within-participants manipulations. Results revealed significant main effects of Attention, F (1, 46) = 72.92, MSE = .004, $p < .001$, $\eta^2 = .61$, and of Face Group, F (1, 46) = 12099.69, MSE = .013, $p < .05$, $\eta^2 = 1.00$, as well as a marginally significant effect of Task, F (1, 46) = 4.06, MSE = .002, p = .05, $\eta^2 = .08$. There was a significant Group X Task interaction, F (1, 46) = 6.94, MSE = .002, $p < .05$, $\eta^2 = .13$, but all other interactions were non-significant, ps > 08. To identify the source of the interaction, separate ANOVAs were conducted for each Face Group (Upright and Inverted).

The Upright group showed significant main effects of Attention, *F* (1, 23) = 42.54, *MSE* = .004, *p* < .001, η^2 = .65, and Task, *F* (1, 23) = 13.06, *MSE* = .002, *p* < .005, η^2 = .36. The interaction between Attention and Task was, however, not significant, *F* (1, 23) = 2.71, *MSE* = .004, *p* = .11, η^2 = .11. Paired samples t-tests indicated that, in the Baseline condition, *t*(23) = 4.93, *SE* = .010, *p* < .001, performance was worse on the Featural than on the Configural task. In the DA condition, however, the featural and configural task accuracy did not differ, *t*(23) = 0.60, *SE* = .018, *p* = .55, *ns* (see Table 5). Importantly, this indicates that, under dual-task conditions, the distracting tasks did not differ in difficulty. As in Experiment 2, both the Featural, *t* (23) = 4.44, *SE* = .013, *p* < .001, and Configural, *t* (23) = 4.89, *SE* = .020, *p* < .001, tasks were performed worse under DA than under Baseline.

The Inverted group also showed a significant main effect of Attention, *F* (1, 23) = 31.97, *MSE* = .005, *p* < .001, η^2 = .58. However, the main effect of Task, *F* (1, 23) = .16, *MSE* = .003, *p* = .69, η^2 = .01, as well as the interaction between Attention and Task, *F* (1, 23) = .70, *MSE* = .003, *p* = .41, η^2 = .03, were not significant. Paired samples t-tests indicated that the main effect of Attention was characterized by both the Featural, *t* (23) = 4.44, *SE* = .013, *p* < .001, and Configural, *t* (23) = 4.89, *SE* = .020, *p* < .001, task performance being worse under DA than under Baseline (see Table 5 for means).

Table 5

Experiment 3: Mean Distracting Task Performance During the Memory Task For Upright vs Inverted Faces in Each Attention and Task Condition (Standard Errors in Parentheses)

	Baseline		Divided Attention	
Memory Group	Featural	Configural	Featural	Configural
Upright faces	.93 (.01)	.98 (.01)	.87 (.01)	.88 (.02)
Inverted faces	.92 (.01)	.91 (.01)*	.83 (.02)	.83 (.02)*

* Distracting faces are low-pass filtered

3.2.3 Discussion

Experiment 3 showed a significant interaction, which was driven by different interference patterns depending on whether the target face was presented upright or inverted. When the to-be-remembered faces were upright, and hence processed configurally (Farah et al., 1998; Tanaka & Farah, 1991; 1993), memory accuracy was significantly worse in the DAC than in the DAF condition. Conversely, when the to-be-remembered faces were inverted, thereby engaging featural processing (Yin, 1969), memory performance was significantly worse in the DAF than in the DAC condition. My results provide support for the idea that memory interference at retrieval results from competition not only from similar materials in the concurrent tasks but also from competition for common processing resources. To ensure that the interaction was not in any way driven by differences in distracting task difficulty, I collected further data using a simultaneous continuous tone classification task to gauge how demanding each distracting task was.

3.3 Experiment 4

It is possible that memory performance could be impaired in dual-task situations for reasons other than competition for processing resources. Indeed, if one task was simply more difficult or attention demanding in general, than another, retrieval differences could appear. Here I designed an experiment to gauge whether there were any differences in difficulty or attentional requirements between my featural and configural distracting tasks. A continuous response time (CRT) task was completed, whereby I paired each of the distracting tasks with one requiring continuous tone classification. Differences in difficulty or attentional demands on the featural and configural distracting tasks would be reflected in differentially impaired performance on the tone classification task, when performed concurrently with each. If, however, CRT performance is not differentially affected by the concurrent distracting task, then there is no reason or evidence to believe that my tasks exerted any significant differences in level of difficulty or resource requirements in Experiment 3 that could explain why one distracting task affected memory more than the other. Specifically, if one distracting task was more difficult than another, one would expect to see slower response times, or fewer tones correctly classified, on the CRT task when it was performed concurrently with a more difficult than with an easier distracting task. Additionally, because participants could adopt a strategy of simply randomly responding to as many tones as possible regardless of accuracy, another measure was needed to ensure that participants were successfully performing the task, and not adopting this approach. Accordingly, I also chose to examine number of tones correctly classified as a *proportion* of the total tones that they were able to classify (correctly or incorrectly). Through these two measures, the CRT acts as an indirect index of the relative difficulty of the distracting tasks.

3.3.1 Method

Participants. Twenty-four naïve undergraduate students (11 female) at the University of Waterloo completed the experiment. Their ages ranged from 16 to 25 (*M* = 19.72, *SD* = 2.21), with between 12 and 18 years of education (*M* = 14.04, *SD* = 1.97). The experiment was completed either for course credit or for remuneration. All participants had normal or corrected to normal vision, and learned English before the age of 7.

Materials. Face stimuli were identical to those used in the distracting tasks in Experiment 3. Low, medium, and high tones were created using Audacity software.

Procedure. Stimulus presentation and response collection was controlled using E-prime v2.0 software (Psychology Software Tools Inc., Pittsburgh, PA) via an IBM computer. Participants completed the CRT task, and each of the distracting tasks (inverted featural, configural, and low-pass-filtered (LPF) configural) alone, as well as performing the CRT task concurrently with each of the distracting tasks. Order of conditions was counterbalanced.

CRT task. Participants were tasked with classification of computer-generated tones as low, medium, or high. When the participant had classified a tone, the next tone was presented. If no response was given within 3 seconds, the next tone was presented. This task was performed alone, and paired with each of the distracting tasks.

Distracting tasks. Distracting tasks were completed exactly as in the main experiment; however a Serial Response box with voice onset relay was used to collect response time (RT) for spoken responses.

3.3.2 Results

Tones Correctly Classified. The number of tones classified correctly was compared using ANOVA. Mauchly's test of Sphericity was significant, $X^2(5) = 18.55$, $p < .005$, so the Greenhouse-Geisser correction was applied. There was a main effect of Condition, $F(1.96, 45.10) = 38.56$, $MSE = 239.92$, $p < .001$, $\eta^2 = .63$: Participants accurately classified more tones during baseline than under dual-task conditions with the featural, $t(23) = 6.38$, $SE = 4.83$, $p < .001$, configural, $t(23) = 7.91$, $SE = 4.18$, $p < .001$, and LPF configural task, $t(23) = 7.57$, $SE = 4.13$, $p < .001$ (Table 6). All other differences were not significant, $p > .42$ (See Table 6 for means).

Proportion Correct. A repeated measures ANOVA was conducted using proportion of tones correctly classified as a dependent variable. Condition (baseline, featural, configural, low-pass filtered (LPF) configural) was included as a within-participants factor. Mauchly's test of Sphericity was significant, $X^2(5) = 12.06$, $p < .05$, so the Greenhouse-Geisser correction was applied. There was a main effect of condition, F $(2.36, 54.20) = 21.58$, $MSE = .019$, $p < .001$,

$\eta^2 = .48$. This was driven by participants classifying tones with more accuracy at baseline (M = .75, SE = .04) than while completing the featural (M = .52, SE = .04) task, t (23) = 5.09, SE = .045, $p < .001$, configural (M = .50, SE = .05) task, t (23) = 6.04, SE = .040, $p < .001$, and LPF configural (M = .52, SE = .04), t (23) = 7.36, SE = .031, $p < .001$, tasks. All other differences were not significant, all ps > .45 (See Figure 6, Table 6 for means).

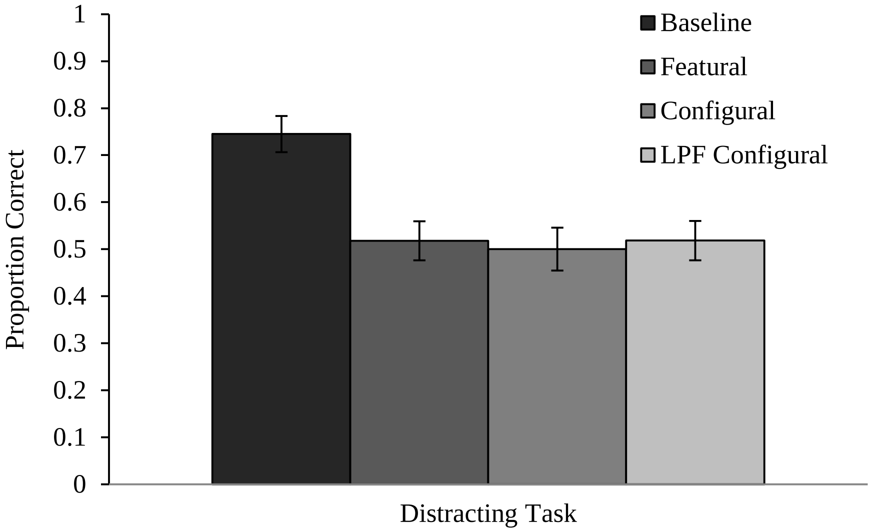

Figure 6. Proportion correct for classification of tones during a full attention baseline condition, and under dual-task conditions with either the featural, configural or low-pass-filtered (LPF) distracting task.

Response Time. The response time for tone classification was analyzed in the same way. Mauchly's test of Sphericity was significant, $X^2(5) = 15.58$, $p < .05$, so the Greenhouse-Geisser correction was applied. There was a main effect of condition, F (2.17, 49.85) = 8.45, MSE = 37018.39, $p < .005$, $\eta^2 = .27$. This was driven by participants' responding more quickly at baseline (M = 875.46, SE = 32.94) than while completing the featural (M = 1078.62, SE = 48.51) task, t (23) = 4.45, SE = 45.64, $p < .001$, configural (M = 1074.28, SE = 62.02) task, t (23) =

3.21, *SE* = 62.01, $p < .005$, and LPF configural (*M* = 1050.97, *SE* = 45.43) task, *t* (23) = 3.49, *SE* = 50.34, $p < .005$. All other differences were not significant, all *p*s > .43 (See Table 6 for means).

Table 6

Mean Performance Measures on the Continuous Reaction Time (CRT) Task Under the Full Attention Baseline Condition and Under Dual-Task Conditions With Each Distracting Task (Standard Errors in Parentheses)

	Condition			
Measure	Baseline	Featural	Configural	LPF Configural
Correct Tones	67.40(5.75)	36.58(4.15)	34.37(4.15)	36.16(4.09)
% Correct	0.75(0.04)	0.52(0.05)	0.50(0.05)	0.52(0.04)
Response Time	875.46(32.94)	1078.62(48.51)	1074.28(62.02)	1050.97(45.43)

Face Task Performance. Performance on the face tasks, as measured by proportion correct, was analyzed, with Attention (Baseline or DA) and Task (featural, configural LPF configural) included as within-participant factors. There was a main effect of Attention, *F* (1, 23) = 43.67, *MSE* = .02, $p < .001$, $\eta^2 = .66$, a main effect of Task, *F* (2, 46) = 7.30, *MSE* = .013, $p < .005$, $\eta^2 = .24$, and a significant Attention x Task interaction, *F* (2, 46) = 4.36, *MSE* = .01, $p < .05$, $\eta^2 = .16$. To determine the nature of the interaction, baseline and DA conditions were analyzed separately.

In the Baseline condition, there was a main effect of Task, *F* (2, 46) = 14.38, *MSE* = .008, $p < .001$, $\eta^2 = .38$. Paired samples analyses revealed that this was driven by participants responding correctly to a higher proportion of faces in the configural task (*M* = .97, *SE* = .01) relative to both the featural (*M* = .87, *SE* = .02) task, *t*(23) = 4.94, *SE* = .019, $p < .001$, and the LPF configural (*M* = .84, *SE* = .02) task, *t* (23) = 6.65, *SE* = .02, $p < .001$. The featural and LPF configural task were not significantly different from one another, *t* (23) = 1.07, *SE* = .035, $p = .29$.

In the DA condition, the main effect of Task was not significant, *F* (2, 46) = 1.74, *MSE* = .015, *p* = .19, η^2 = .07. The featural (*M* = .77, *SE* = .03), configural (*M* = .75, *SE* = .04) ,and LPF configural (*M* = .70, *SE* = .04) tasks were not significantly different from one another (See Table 7 for means).

Table 7

Experiment 4: Mean Distracting Task Accuracy and Response Time During Baseline and Dual-Task Conditions With Each Distracting Task (Standard Errors in Parentheses)

		Distracting Task		
Condition	Measure	Featural	Configural	LPF Configural
Baseline	Accuracy	0.87(.02)	0.97(.01)	0.84(.02)
	Response Time	813.71(21.69)	747.99(25.47)	936.79(22.13)
Divided Attention	Accuracy	0.77(.03)	0.75(.04)	0.70(.04)
	Response Time	1083.61(24.25)	1086.52(21.76)	1128.38(19.69)

Face Task Response Time

Participants' response times when completing the face tasks were also compared. There was a main effect of Attention, *F* (1, 23) = 144.83, *MSE* = 18121.99, *p* < .001, η^2 = .86, and of Task, *F* (2, 46) = 28.34, *MSE* = 7012.50, *p* < .001, η^2 = .55, and a significant Attention x Task interaction, *F* (2, 46) = 25.57, *MSE* = 2487.13, *p* < .001, η^2 = .53. To determine the nature of the interaction, baseline and DA conditions were analyzed separately.

In the baseline condition, there was a main effect of Task, *F* (2, 46) = 49.62, *MSE* = 5034.01, *p* < .001, η^2 = .68. Paired samples analyses revealed that this was driven by faster response times in the configural task (*M* = 747.99, *SE* = 25.47) relative to both the featural task (*M* = 813.71, *SE* = 21.69), *t* (23) = 3.77, *SE* = 17.44, *p* < .005, and the LPF configural task (*M* = 926.79, *SE* = 22.13), *t* (23) = 8.08, *SE* = 22.13, *p* < .001. The featural and LPF configural tasks were also significantly different from one another, *t* (23) = 8.10, *SE* = 13.97, *p* < .001.

In the DA condition, the main effect of Task was also significant, *F* (2, 46) = 4.05, *MSE* = 3717.40, $p < .05$, $\eta^2 = .15$. Paired samples analyses revealed that response times in the featural task (*M* = 1083.61, *SE* = 24.25) were significantly faster than in the LPF configural task (*M* = 1128.38, *SE* = 19.69), *t* (23) = 2.65, *SE* = 16.92, $p < .05$. Comparisons involving the configural task (*M* = 1086.52, *SE* = 21.76) were not significant (See Table 7 for means)

3.3.3 Discussion

To rule out distracting task difficulty as an alternative explanation for the observed pattern of memory interference from Experiments 2 and 3, I conducted extensive analyses of the relative difficulty or resource demands of each distracting task. Tone classification on a concurrently performed CRT task did not differ as a function of which distracting task was simultaneously performed. This was true for all measures, including number of tones correctly classified, proportion correct, and response time. These results suggest that no distracting task was more difficult than another.

I also analyzed performance on the distracting tasks themselves. Although there were some marginal differences between tasks, the differences were in the opposite direction one would expect if it was the case that the effects were driven by task difficulty. To clarify, the featural task was slightly more difficult than the configural task when testing memory for upright faces. Similarly, the auditory CRT data showed that accuracy was lower in the featural as compared to the configural distracting task. The expected outcome, if task difficulty was driving the effect, would be that memory performance would be challenged more by the featural task, which is precisely the opposite of what my memory data show. Response time analyses from the CRT revealed that response times for the featural task were significantly faster than the response times in the LPF configural task. Again, if task difficulty was an influential confound, one would expect that this more difficult LPF task should cause more interference than the easier featural task, precisely the opposite pattern for that shown in the memory data. Taken together, these results suggest that, if anything, the slight task difficulty differences were working against the effect seen in Experiment 3. Given that the predicted effect was still clearly displayed, the distracting task and CRT results bolster the argument of the current work.

3.4 Discussion of Experiments in Chapter 3

In line with Experiment 1 as well as previous findings (Fernandes, Davidson, Glisky, & Moscovitch, 2004; Fernandes, Moscovitch, Ziegler, & Grady, 2005; Fernandes, Pacurer, Moscovitch, & Grady, 2006; Fernandes & Moscovitch, 2000; 2002, 2003), Experiments 2 and 3 also showed significant reductions in memory accuracy when retrieval was performed simultaneously with a distracting task involving similar materials (i.e. both face stimuli).

Importantly for this thesis, across two experiments in this Chapter, I tested whether episodic retrieval of studied faces was susceptible to interference effects from distracting tasks, not just from similar materials. Past research suggests that retrieval interference occurs primarily due to material-specific overlap between concurrent tasks. I tested whether interference could also arise from processing-specific overlap. Two distracting tasks were crafted such that they involved the same materials (faces) as the primary recognition task, but engaged either configural or featural processing.

I showed that face memory retrieval is sensitive to interference from other face-related tasks (Experiments 2 and 3). More importantly, I showed that the magnitude of interference is processing-specific, and modulated by the degree of overlap of the types of processing required by the concurrently performed tasks (Experiment 3). That is, I found a crossover interaction: Memory for upright faces was worse in the DAC than in the DAF condition, whereas the reverse was true for inverted target faces, as evidenced by a reliable interaction. Findings suggest that the magnitude of memory interference under DA conditions at retrieval depends on the extent to which the processing demands of the distracting and retrieval tasks overlap.

Our results also contribute to the existing knowledge on the ways in which faces can be processed. Because I observed different interference patterns across two DA conditions that differed only in their requirement for either featural or configural processing, it seems that these processes are dissociable. Many argue that the two are highly interwoven and thus difficult to tease apart (McKone, Martini, & Nakayama, 2003). In the present work however, the inversion effect, combined with basic manipulations of task demands, successfully biased participants toward a specific means of processing faces, providing a paradigm to tease these apart and show that they are indeed separable.

Chapter 4: General Discussion

The goals of this thesis were to extend the study of the effects of DA at retrieval to more diverse verbal stimuli, using Chinese characters, as well as to test the generalizability to the visuo-spatial domain by examining interference with memory for faces. Specifically, my aim was to demonstrate a crossover interaction, depending on the degree to which the processing demands of a memory task and a distracting task overlap. Most previous studies of DA effects on episodic retrieval examined memory for English verbal stimuli. To extend this work, I used Chinese characters, which were familiar verbal materials for the bilingual but not for the monolingual participants, and also a more visuospatially processed stimulus. Only one study prior to this has examined memory for visuo-spatial information, although that work used unfamiliar, lab-created stimuli (grids; Fernandes & Guild, 2009) thus the generalizability of reported effects of DA at retrieval across verbal materials as well as to the visual domain could be questioned.

In Chapter 1, Chinese logographs were the to-be-remembered stimuli; they require a high degree of visuospatial scrutiny because the orthographic appearance of characters does not directly dictate pronunciation of the word (Chen & Yuen, 1991; Perfetti et al., 2010). English word processing, on the other hand, necessitates phonological processing to retrieve meanings (Jared et al., 1999; Newman, Jared, & Haigh, 2012). When comparing retrieval of stimuli presented in each of these two languages, I saw that the language status of the participant, and hence the ability to represent stimuli visuo-spatially in the case of Chinese and phonologically in the case of English words, determined the pattern of memory interference from distracting tasks that also required visuo-spatial or phonological processing.

Because of the importance of visuospatial processing in understanding/reading Chinese characters, a visuo-spatial distracting task interfered more than did a phonological distracting task with the bilingual group's retrieval of word representations. Conversely, the English-only group's (Fernandes & Guild, 2009) dependence on phonology resulted in the opposite trend, with phonological distraction being more costly. These results suggest that the processing-specific account is not unique to English words, but applies to logographic language as well.

Although Chinese logographs are visuospatial in nature, their study did not truly address whether the processing-specific account is generalizable to visuo-spatial stimuli. This is because despite requiring visuo-spatial processing, they still function largely as a verbal stimulus. For this reason, faces were chosen as the stimuli for Chapter 2 by virtue of having an exposure frequency comparable to that of words, but also because they seem to engage two different types of processing (Goffaux & Rossion, 2006; Rhodes, 1988). In both Experiment 2 and 3, memory accuracy for studied faces was reduced under DA, relative to FA conditions, with distracting tasks that also used face stimuli. This finding is in line with the material-specific account of DA effects at retrieval put forward by Fernandes and Moscovitch (2000). Thus the generalizability of this effect to visuo-spatial stimuli was supported.

Although my study and past research is consistent with a material-specific account of DA effects on episodic retrieval, I sought to test whether there was any evidence for a processing-specific account. Previous work has suggested that interference occurs at retrieval due primarily to competition for common material-specific resources (Fernandes et al., 2004; 2006; Fernandes & Moscovitch, 2000; 2002; 2003). In other words, memory for words was impaired in the dual task condition in these studies because the simultaneously performed distractor task also required word processing. Subsequent research posited an alternative account, such that it may not be the materials themselves but the type of processing required in response to the materials that accounts for memory interference (Fernandes & Guild, 2009). In Experiment 3, I showed that memory for upright faces was more susceptible to interference from a configural than from a featural task, whereas memory for inverted faces was disrupted more by a featural than by a configural distractor task. This finding supports a processing-specific account of memory interference at retrieval.

Limitations

Our work examining how language differences influenced susceptibility to interference (Experiment 1) showed that processing-specific interference does occur. The memory stimulus and distracting task stimuli were, however, presented in different modalities (visual recognition with auditory distracters). As previously discussed, this is not an ideal paradigm for testing whether processing-specific, in addition to material-specific, overlap plays a role in determining magnitude of detriment to memory retrieval. Thus, my Experiment 1 shares some shortcomings with previous work (Fernandes & Guild, 2009). To overcome these potential limitations, I designed Experiments 2-4, wherein memory and distracting stimuli were displayed in the same modality.

Although my Experiments 2-4 do support processing-specific interference, there are a number of limitations related to the chosen paradigm. In Experiments 2 and 3, because the two faces were presented side by side, it is possible that task-switching (rather than dual-tasking) may have played a role in disrupting recognition performance. This is an issue that is unavoidable in dual-task research but, uniquely in this case, because both stimuli were presented visually side by side. I included a number of methodological manipulations to mitigate the effect of task switching: Faces for the target versus distracting task varied from trial-to-trial to the left or right side of the screen to avoid having participants develop a strategy of always responding first to the stimulus on the right, then the left. As well, the stimulus duration was sufficiently short that task switching was an improbable strategy.

The interrelation between configural and featurally-based processing in representing faces is the subject of spirited debate among face researchers. As such, it is difficult to argue that I completely dissociated the two in my experiments. This is a limitation of my study, although it is one that would hurt rather than help my chances of uncovering the significant crossover interaction that I found. Given the crossover interaction in the effects of configural and featural distracting tasks on memory for faces, my manipulations showed experimentally that the two can be teased apart. A stronger effect would likely be revealed, however, if the two processing types could be fully separated. Unfortunately, methods previously used to more completely dissociate the two involve presenting the face with visual noise, in the periphery, superimposed with another face, or some other drastic transformation (McKone, Martini, & Nakayama, 2003).

Because my processing manipulations required only minor transformations of the stimuli, most notably inversion, there remains a possibility that orientation of the face plays a role in determining patterns of memory interference. Some may argue that, by inverting the faces, I may have separated the material set (faces) into two material subsets (upright, inverted). Accordingly, it would be important for future work to determine whether processing differences play a role in determining dual-task effects on memory for visual stimuli without changes in orientation of the distracting task.

Implications

Previous work had shown that processing-specific interference occurs in short-term memory (Pellegrino, Siegel, & Dhawan, 1976a). Thus the current study not only supports previous findings (Fernandes & Guild, 2009) but also supports of the generality of this account for understanding how DA affects both short and long term memory similarly. Based on this thesis, the magnitude of episodic memory interference—for words, logographs, and faces at least—may be due to the additive effect of material-specific and processing-specific competition between concurrent tasks (See Figure 7 for hypothetical data).

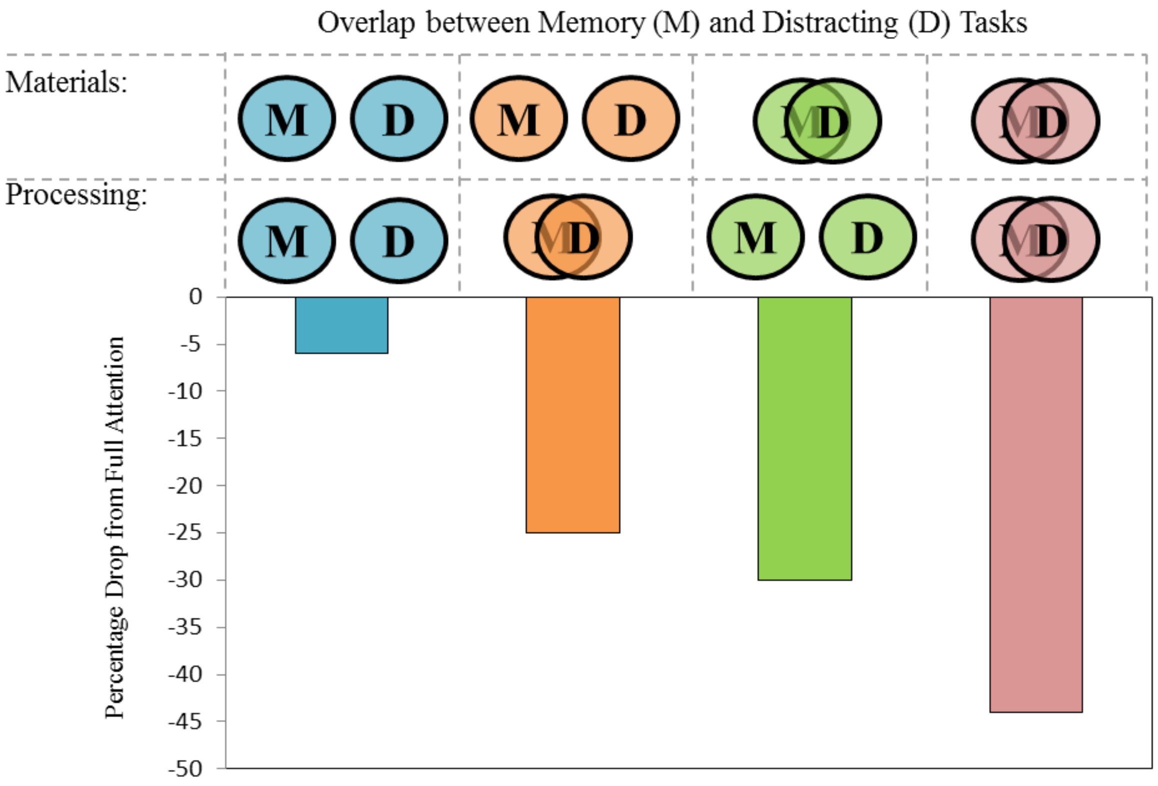

Figure 7. Expected patterns of memory interference (percentage drop from full attention) from distracting tasks which vary in overlap in materials and processing required. Venn diagrams represent the overlap, or lack thereof, of either materials or processing between the memory task and distracting task. The right-most bar is the combination of memory and distracting tasks that most parallels the current work.

Multiple versus Single Pools of Attention

If processing overlap successfully accounts for interference patterns across a number of different types of stimuli, we can conclude that retrieval is not automatic (Baddeley et al., 1984) or obligatory (Craik et al., 1996) as others have suggested, but that it uses a specific pool of resources based on the type of processing required. Proponents of resource accounts hold that when these resources are depleted by a distracting task (which in the current work, requires the same type of processing), retrieval will falter or fail. Therefore, my results extend the view that attention may be derived from multiple, independent, modality-specific pools of attentional resources, by suggesting that resources are further differentiated into processing-specific pools. My results are difficult to remedy with the idea that attention is not subserved by a single pool of general resources, as has been suggested (Kahneman, 1973; Sorqvist, Stenfelt, & Ronnberg, 2012). Instead, the observed crossover interaction is consistent with different pools of resources that are specific to a certain modality (visual/auditory) or code (spatial, verbal) (in line with Wickens, 2008). Given that my results showed differential interference, depending on overlap in processing requirements and stimulus type, the data provide clear support for multiple independent resource pools, with the caveat that resource pools are processing-specific.

Capacity Sharing vs. Response-Selection Bottleneck

My findings have a number of implications for understanding the detrimental effects of dual-tasking, furthering our knowledge of the resources required for word and face processing, and especially for predicting how memory is affected under conditions of limited attention. Pashler's (1989) two component theory outlined the relative contributions of a 'response-selection bottleneck, and 'capacity sharing,' to dual-task interference. This theory was primarily concerned with differences in response time. Accordingly, his account did not attempt to explain accuracy differences due to dual-task interference, which was the focal point of the current research. Still, my experiments provide support for a capacity sharing model of episodic retrieval, which suggests that when two tasks occur concurrently there is competition for limited processing resources. Capacity sharing suggests that there is a limited pool of resources (be it general or specific, my results indicating the latter); any differences observed as a result of dual-tasking occur because this limited pool is diminished, hampering performance across both tasks. The memory accuracy results shown here suggest that when processing-requirements of two tasks do overlap, there are significantly larger interference effects than when they do not.

Proposed Retrieval Mechanism

Though my data do not speak specifically to the brain basis of memory retrieval, the behavioral results lead me to speculate about possible extensions or implications for the neural processes underlying memory retrieval. Here I outline one potential account of how these behavioral outcomes could be reflected in the brain. I propose that effective retrieval may be driven by a 'reassembly' of all components present at encoding, not unlike the component process model put forward by Moscovitch and Umilta (1990). Many conceptualize retrieval as an effortless process whereby an intact memory is simply grabbed from long-term store, not unlike opening a file on a computer. I would argue that the process is much more complex. Any experience or piece of studied information is encoded not as a single unit, but as a collection of elements of that experience. These include context, time, place, and, I would like to suggest, material type and processing type. At encoding, all of these elements are integrated by the hippocampus. Over time, these memories are distributed to cortical regions subserving their processing, enabling long-term storage, although this process is likely never fully independent of the hippocampus (Winocur, Moscovitch & Bontempi, 2010). What degrades over time and as a result of dual-tasking is not the elements themselves, but the connections between them and from them to a retrieval cue (See Figure 8). Degradation of connections is supported by my finding that when the processing resources required to effectively reiterate the encoding experience are otherwise engaged (and likely overlapping brain regions are activated) at retrieval, performance is hampered. Thus, one element of the memory is rendered inaccessible, weakening the congruency between encoding and retrieval, and therefore the success of retrieval. Thus, memory is not modular, but diffuse across the brain. A cue for retrieval is not a hint at the location of the intact memory, but rather an anchor to which all of the elements are attached. Successful retrieval depends on the integrity of these attachments, and the greater the proportion of 'intact' elements, the greater the likelihood of a successful retrieval. Dual-tasking acts to effectively block off one element, in this case the processing type engaged, thereby weakening memory for the experience as a whole, and decreasing retrieval success.

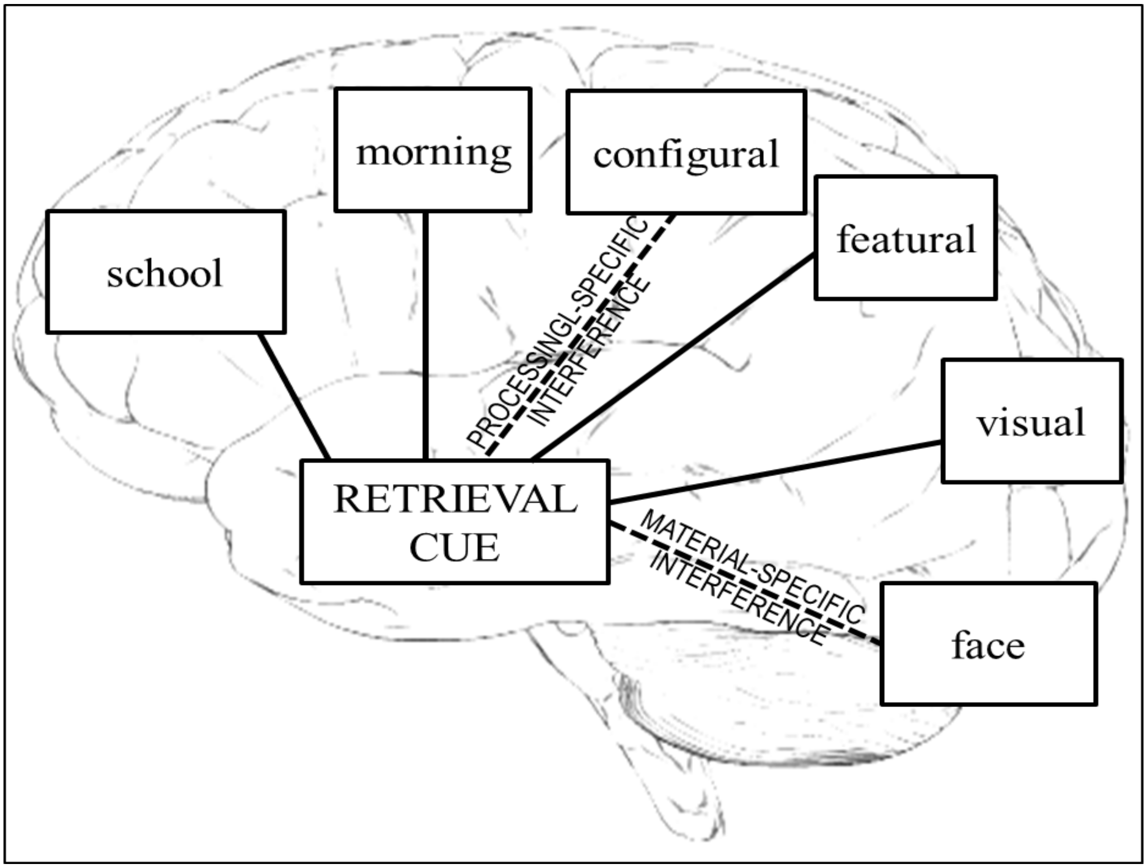

Figure 8. Proposed model of retrieval, and interference with this process, whereby an encoded memory is a combination of the elements of the encoding experience, with successful retrieval resulting from a successful reassembly of the elements. Elements might include where (school) and when (morning) information was encoded, what type of material it was (face), the modality in which it was presented (visual), and how it was processed (configural or featural). Dual-tasking can lead to degradation of connections with specific elements, depending on overlap of processing demands of the distracting task with the memory task, weakening the memory trace.

Future Directions

It is important that future research determine the extent to which processing type and materials each play a unique role, and whether the findings here are applicable to other types of memory and sets of stimuli. These are important questions to test, as they will indicate the activities or tasks that one could perform while simultaneously trying to retrieve information, without also undermining the retrieval process. Testing the generalizability of these findings to a cross-section of other types of stimuli (objects, rhythms, motor sequences) would allow for a more comprehensive understanding of why and how dual tasking, or DA, affects retrieval of information from memory. One could, for example, test memory retrieval of studied visual objects, which required global versus local processing. This would be an important demonstration that the processing-specific interference found in the current work applies to all visual stimuli and is not unique to faces. When paired with either a global or local distracting task, I would predict an interaction, such that the greater the degree of processing overlap, the greater the detriment to memory performance. This maps nicely onto the configural versus featural argument of this thesis, as they both take a ‘forest’ versus ‘the trees’ approach. Stimuli already exist that are well suited to compare global and local processing, such as letters composed of either matching or non-matching letters (as used in Love, Rouder, & Wisniewski, 1999), though for my purposes, visual symbols (global) composed of other symbols (local) may be best, to remove any verbal or phonological component. A global distracting task should interfere more with memory based on global features than would a local distracting task.

To determine whether interference may be incurred by distracting tasks requiring motor sequences, one could ask participants to perform an action that they would typically perform in response to a study word (see Engelkamp & Zimmer, 1989, for work on the Enactment effect). It would follow that these words would be encoded with some form of motor processing. Accordingly, one might expect that when a participant is asked to perform a distracting task where they must tap a motor sequence (taxing motor processing) at retrieval, accuracy for enacted words in particular would be impaired. This is because the memory trace for enacted words necessarily integrates motor information. When access to this element of the memory is restricted during retrieval by the motor distracting task, retrieval will be hampered.

I did show that interference occurred between two tasks using the same materials, but because the experiments in Chapter 3 used only one type of material (faces), I was not able to fully determine the extent to which the material-specific and processing-specific accounts each contributed to the magnitude of interference. I showed a differentially large effect when processing requirements overlapped, suggesting that competition for processing resources is an additional locus of interference, beyond a material-specific account. Neuroimaging research could also determine whether overlap in the activation of brain areas specific to processing requirements drives these effects. Imaging research could test the prediction that activation differences from dual tasks would not be localized in the hippocampal formation, but rather in neocortical regions that communicate with the formation via the entorhinal cortex. The entorhinal cortex provides connections that allow memories to be rooted in context, and recollective in nature. Although not context in the traditional sense, the current work suggests that processing and material type are seemingly necessary elements of a memory. Thus, when a dual-task is completed, connections between the regions underlying processing types and the hippocampus may be rendered inaccessible, such that the specific element of the experience does not aid the retrieval process, regardless of the integrity of the cue (Curran, 2000; Yonelinas, Otten, Shaw, & Rugg, 2005). These are hypotheses that are conducive to future neuroimaging exploration.

4.1 Conclusion

Overall, I showed that interference with episodic memory retrieval is processing-specific. I determined that the mode of representation of linguistic information determines its susceptibility to retrieval interference from different distracting tasks (Chapter 1). I showed that episodic memory for faces is sensitive to interference from other face-related tasks (Chapter 2, Experiment 2 and 3). More importantly, I showed that the magnitude of interference was modulated depending on whether the memory and distractor tasks had overlapping processing requirements (Chapter 2, Experiment 3). My findings support and extend a processing-specific account of dual-task interference on episodic retrieval, and show that this account is generalizable to other common stimulus sets beyond English words. In everyday life, whether by choice or not, we are often placed in situations requiring multi-tasking. As such, it is critical to be aware of the situations that allow memory to thrive, and conversely to break down. I propose that memory retrieval requires processing-specific resources specific to the studied information. When that required processing type is otherwise engaged, a prevalent occurrence in modern life, successful retrieval will be compromised.

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