

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

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Abstract

We inferred the processes critical for episodic retrieval of faces by measuring susceptibility to memory interference from different distracting tasks. Experiment 1 examined recognition of studied faces under full attention (FA) or each of two divided attention (DA) conditions requiring concurrent decisions to auditorily-presented letters. Memory was disrupted in both DA relative to FA conditions, a result contrary to a material-specific account of interference effects. Experiment 2 investigated whether the magnitude of interference depended on competition between concurrent tasks for common processing resources. Studied faces were presented either upright (configurally-processed) or inverted (featurally-processed). Recognition was completed under FA, or DA with one of two face-based distracting tasks requiring either featural or configural processing. We found an interaction: memory for upright faces was lower under DA when the distracting task required configural than featural processing, while the reverse was true for memory of inverted faces. Across experiments, the magnitude of memory interference was similar (a 19% or 20% decline from FA) regardless of whether the materials in the distracting task overlapped with the to-be-remembered information. Importantly, interference was significantly larger (42%) when the processing demands of the distracting and target retrieval task overlapped, suggesting a processing-specific account of memory interference.

Keywords: divided attention, episodic memory, interference, configural, featural

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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 explored, though the locus of memory interference effects at retrieval remains in dispute. Our earlier work suggests that interference arises as a result of competition for material-specific representational systems (Fernandes & Moscovitch, 2000), while more recent research has alluded to the possibility that interference arises due to competition for a limited pool of shared processing resources (Fernandes & Guild, 2009). The current work contrasted these two accounts of interference effects at retrieval. Further, few researchers have ventured beyond examining memory for word lists. As such, another goal of the current work was to expand the scope of dual-task research to visuo-spatial stimuli to allow the formation of a more generalized understanding of the consequences these conditions present to long-term memory.

Encoding vs. Retrieval

Previous research has shown that the effects of dual-tasking, or divided attention (DA), on memory differ depending on whether 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 from DA during encoding. In contrast, negative effects from DA during retrieval were non-existent, leading researchers to conclude that episodic retrieval, at least for words, is an automatic process (Baddeley et al., 1984). Subsequent work (Craik, Naveh-Benjamin, & Anderson, 1996) showed negligible interference with recall of words, from DA conditions at retrieval, when the distracting task consisted of a computer-based visuo-spatial tracking task. They did, however, document large costs to performance on the distracting task under DA conditions, leading them to conclude that although retrieval appeared to occur obligatorily in the sense that memory was minimally affected, it was not an 'automatic' process, but was in fact quite attention-demanding as indexed by the significant costs to distracting task performance. These findings were particularly surprising, in that they displayed a stark contrast between effects of DA at encoding compared to at retrieval, which is contrary to the view that retrieval and encoding processes were highly similar (Kollers & Roediger, 1984; Morris, Bransford, and Franks, 1977; Tulving, 1983).

Material-Specific Interference

The lack of a large effect at retrieval was quite puzzling, as it is often conceived as an effortful process, easily thwarted by distraction. Fernandes and Moscovitch (2000) later showed that large and significant memory interference could indeed occur, specifically when the material in the distracting and target memory task overlapped. In that work, 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 small detriments of 13% to recall, comparable to that reported by others (Craik et al., 1996; Anderson et al., 1998), the word-based distracting task produced a substantial 30% decrease in recall from full attention (FA) levels. Based on this

finding, Fernandes and Moscovitch proposed that interference with retrieval could occur, but that it was material-specific. That is, interference depended on whether the to-be-remembered information, and the distracting task, competed for a common material set or representational system (Fernandes & Moscovitch, 2000). It was 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), card sorting, or digit based (Baddeley et al., 1984) and thus were dissimilar to those in the word-based memory task.

The hypothesis that interference with episodic memory is material-specific was supported by a number of subsequent studies (Barnes & Dougherty, 2007; Ciaramelli, Gheiti & Borsotti, 2009; Clarke & Butler, 2008; Fernandes, Davidson, Glisky & Moscovitch, 2004; Fernandes, Pacurar, Moscovitch & Grady, 2006; Wais, Rubens, Boccanfuso, & Gazzaley, 2010; Wais, Martin & Gazzaley, 2012, but see Hicks & Marsh, 2000; Knott & Dewhurst, 2007). The generalizability of this claim, however, is limited because in most of these previous studies, only memory for words was assessed. Whether these findings would apply to other stimulus types, for example visuo-spatial stimuli, remains an open question. Further, it is unclear whether material-specificity represents an all-encompassing explanation, or whether other factors may also contribute to the previously observed patterns of data. For example, while the material-specific account seems a likely candidate for explaining memory interference at retrieval, one could suggest that overlap in type of processing required of the concurrent tasks either contributes to, or better explains the effect. Prior work has not explored this possibility.

Processing-Specific Interference

Though not assessed within long-term memory, the idea of processing-specific (as opposed to material-specific) interference with memory performance has been previously been shown on

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 (1975, 1976a, 1976b) tested whether short-term memory was differentially affected by distraction, depending on whether the encoded information was verbal (words) or visual (pictures). Results across several experiments indicated that acoustic distraction led to a larger reduction in short-term memory for words than did pictures, whereas visual distraction led to the opposite outcome, such that performance reductions were larger in memory for pictures.

The idea that competition for common processing resources could account for memory interference effects has not been extended systematically to long-term memory. However, our recent research has alluded to this alternative locus for retrieval interference. Fernandes and Guild (2009) compared memory for visuo-spatial grid patterns, or for words, when retrieval occurred under 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 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. Subsequent work (Fernandes, Wammes, & Hsaio, 2013) was designed to probe representations in memory by taking advantage of individual differences in how participants are able to encode and store information. Specifically, we compared interference on a recognition task for simplified Chinese characters, or English words, when performed

concurrently with either a phonological or visuo-spatial distracting task, in groups of participants who vary in their experience with such characters. Chinese speakers process and retrieve simplified Chinese characters visuo-spatially (Zhang, Xiao & Weng, 2012). We showed that this group had more memory interference for such characters, from a visuo-spatial than a phonological distracting task. The opposite pattern was found in English monolinguals retrieving English words, which is more reliant on phonological processing (Jared, Levy, & Rayner, 1999).

The current study

There are a few critical shortcomings in the previous studies that preclude any concrete conclusions about the locus of interference from DA at retrieval. 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 are not commonly experienced or familiar, they are not an ideal comparison for verbal stimuli, which we use daily. Moreover, the visuo-spatial distracting task was presented auditorily, so it is highly unlikely that it was processed in the same way as a visually presented grid pattern. Accordingly, this past work is unlikely to index the magnitude of the effect of true processing-specific interference in a dual-task paradigm. The Chinese characters used by Fernandes et al. (2013), though visual in nature, are also not ideal, as they are simply another form of verbal stimulus, thereby limiting generalizability of a processing-specific account. The current research examined memory for unfamiliar faces, a more ubiquitous visuo-spatial stimulus, devoid of phonological content.

In the current study, the feasibility of a processing-specific account of interference from DA conditions at retrieval was systematically examined. We hypothesized that memory performance would suffer more under conditions in which the processing requirements of the distracting task overlapped with the requirements of the target memory stimulus. We predicted that when

processing-specific overlap in task demands was present, interference would be greatest, followed by material-specific overlap alone, with the lowest magnitude of interference occurring with unrelated (neither material- nor processing-specific) distracting tasks. Our paradigm allowed us to evaluate first whether material-specificity was critically needed to observe significant memory interference effects from DA at retrieval (Experiment 1), and second, whether a processing-specific account is valid, or potentially superior to a material-specific account, in explaining interference with episodic retrieval of visuo-spatial stimuli (Experiment 2, combined analysis).

Experiment 1

The goal of Experiment 1 was to determine whether material-specific competition is critically necessary to observe interference with memory retrieval, or whether significant memory interference occurred even without overlap in materials in the concurrent tasks. Participants' recognition of studied faces was assessed either under FA or while simultaneously completing one of two different distracting tasks. Our distracting tasks consisted of inherently verbal materials, though the task instructions were varied to call more on phonological or imagery-based processing. That is, as in Fernandes and Guild's (2009) study, participants either made rhyming, or imagery-based decisions about auditorily-presented letters. According to a material-specific account (Fernandes & Moscovitch, 2000), neither of these tasks should produce substantial interference with memory for faces. This account holds that interference arises as a result of competition for a common representational system or material set. As letters and faces are not of the same material set, no interference should occur. Fernandes and Guild (2009) on the other hand, may predict larger interference when imagery-based processing is emphasized in the distracting task, as such resources would perhaps also be needed to retrieve the faces. We chose

to examine the effects of DA using two distracting tasks that required different decisions so that any interference effects observed could not be dismissed as artefacts of the demands of the particular chosen task. In light of previous work (Baddeley et al., 1984; Craik et al., 1996, Fernandes & Moscovitch, 2000), we predicted little to no interference with memory performance as a result of either of these letter-based distracting tasks. It is highly unlikely that auditorily presented letters and visually presented faces are processed in the same fashion, so neither would have material-specific or overlap with the stimuli (faces) in the target memory task.

Method

Participants. Twenty-four undergraduate students (13 female) at the University of Waterloo took part in the experiment¹. They ranged in age from 18 to 22 ($M = 19.46$, $SD = 1.28$), with between 12 and 16 years of education ($M = 14.25$, $SD = 1.19$). 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.

Face memory task. Stimuli were chosen from a set of 304 faces from the Glasgow Unfamiliar Face Database (GUFDB; 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. The chosen 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).

Faces were randomly assigned to three separate lists of 40 for use in the target memory task. Within these lists, 20 faces were randomly selected to be lures and 20 to be targets. 20 remaining faces were preserved for use in the practice phase of the experiment. Within each set

of 40, there was an equal gender distribution. Within the sets of 20 targets or lures, 10 faces were female.

Distracting tasks. The same stimuli were used for both the phonological and imagery-based 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 with the letter followed by silence, such that each .wav file was exactly 1500 ms in duration.

Procedure. Stimulus presentation and response recording was controlled using E-prime v2.0 software (Psychology Software Tools Inc., Pittsburgh, PA) via an IBM computer with 17 inch monitor. 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. Each task is explained separately, below, followed by a description of how they were administered under DA conditions.

Target recognition task.

Encoding. During each of the three different encoding phases, participants were asked to study 20 pictures of faces for a later memory test. Faces were centrally presented one at a time for 3500 ms, preceded by a fixation cross for 500 ms. After a brief delay (one minute), participants completed the recognition task.

Retrieval. Following each encoding phase, participants completed a retrieval phase in which participants were shown 40 faces, 20 ‘targets’ and 20 ‘lures’. Each trial began with a 500 ms fixation, followed by the face for 1500 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 1 for design).

Phonological distracting task. Participants heard a list of 40 randomly selected letters aloud. Each letter was presented as an audio file for 1500 milliseconds in duration followed by 500 milliseconds of silence. Participants had to judge whether the presented letter rhymed with the long “e” vowel. They 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, or G. If the letter did not rhyme with the long “e” vowel, the participant responded “no” (e.g. letters A, F, H would require a “no” response). Sixteen letters requiring a “yes” response were randomly selected, and presented randomly amongst 24 randomly selected letters requiring a “no” response. The number of trials was set to match the number of recognition trials, such that the onset could be simultaneous with the recognition memory task when completed concurrently.

Imagery 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. For example, the letters B, G, U would require a “yes” response. If the letter, when capitalized, did not contain a curved line, the participant responded “no” (e.g. letters A, E, F would require a “no” response). The experimenter referred to the letters on the computer keyboard to illustrate how participants should visualize the individual letters.

Experimental Phase. After a short practice phase used to familiarize participants with each of the tasks, a baseline measure (i.e. the phonological or imagery task performed alone) of one of the distracting tasks was completed. Next, the three memory conditions were completed. Lastly, baseline performance of the other distracting task was assessed. The order of the baselines was

counterbalanced across participants, as was the order in which the three memory conditions were completed.

For each of the memory conditions, encoding 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 imagery (DAI) conditions, participants had to make their recognition decisions to the faces while simultaneously making phonological or imagery-based decisions to auditorily-presented letters, respectively. For each trial in each DA condition, 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 given following each recognition condition.

Results

Recognition discriminability. Discriminability (d'), which provides a bias-free estimate of recognition performance, was calculated for each participant, and served as the dependent variable. Data were analyzed using repeated measures ANOVA², with Attention (FA, DAP and DAI) as a within-participant factor. There was a significant main effect of Attention, $F(2, 46) = 7.10$, $MSE = .31$, $p < .005$, $\eta^2 = 0.24$.

Simple effects analyses indicated that the effect of Attention was driven by discriminability in the FA condition ($M = 2.38$, $SE = .17$, $CI_{95} [2.06, 2.71]$) being higher than that in either the DAP ($M = 1.81$, $SE = .17$, $CI_{95} [1.50, 2.13]$), $F(1, 23) = 15.74$, $MSE = .49$, $p < .005$, $\eta^2 = .41$, and DAI ($M = 1.93$, $SE = .21$, $CI_{95} [1.53, 2.33]$), $F(1, 23) = 8.49$, $MSE = .58$, $p < .01$, $\eta^2 = .27$, conditions. There was no difference between the DAP and DAI conditions, $F(1, 23) = .42$, $MSE = .76$, $p = .52$, $\eta^2 = .02$, *ns* (See Table 1).

Distracting task performance. Distracting task performance was measured as the proportion of the 40 trials that were responded to correctly. A 2 x 2 repeated measures ANOVA was conducted, with Attention (Baseline, DA) and Task (Phonological, Imagery) as within-participant manipulations. There was a significant main effect of Attention, $F(1, 23) = 18.57$, $MSE = .004$, $p < .001$, $\eta^2 = .45$, with better performance in the Baseline (phonological, $M = 0.99$, $SE = 0.00$, $CI_{95} [0.98, 1.00]$, imagery, $M = 0.99$, $SE = 0.00$, $CI_{95} [0.99, 1.00]$) than DA (phonological, $M = 0.94$, $SE = 0.02$, $CI_{95} [0.91, 0.97]$, imagery, $M = 0.93$, $SE = 0.01$, $CI_{95} [0.90, 0.95]$) conditions. The main effect of Task, $F(1, 23) = .49$, $MSE = .001$, $p > .05$, $\eta^2 = .02$, as well as the interaction, $F(1, 23) = 1.19$, $MSE = .001$, $p > .05$, $\eta^2 = .05$, were not significant.

Discussion

Experiment 1 showed that distracting tasks utilizing materials different than those in the memory task could still produce significant interference with recognition performance. The decline in performance as a result of DA was a 15-20% drop from FA levels, and not as large as has been shown in other studies in which there was material-specific overlap between the recognition and distracting task (>30% drop from FA; Fernandes, Moscovitch, Ziegler, & Grady, 2005). It is important to note as well, that based on previous research (Fernandes & Guild, 2009; Fernandes, Wammes & Hsiao, 2013) suggesting processing-specific interference, the imagery distracting task should have produced significantly more interference than the phonological distracting task. That is, given that the imagery distracting task asks participants to visualize the capitalized form of the letter it could be argued that it ought to have interfered more with retrieval of faces from memory as both had a visuo-spatial component. Both DA conditions in our study, however, led to similarly large interference.

One potential explanation for this could be that faces require more attention to encode subtleties or unique features in order to differentiate them from others on a later test. Accordingly, it is possible that faces are more susceptible to interference from distracting tasks in general than are other stimulus sets (e.g. words). Alternatively, it could be that the distracting tasks were more attention-demanding than tasks used in previous experiments, leading to decrements in recognition accuracy (Hicks & Marsh, 2000). Also of note is that most research addressing similar questions examined memory for verbal materials, leaving few empirical studies to serve as a precedent for comparison with our current results. It is possible that faces, or perhaps visual materials in general are simply more susceptible to interference, though that is a question for future work.

All of the studies reviewed thus far, including our own Experiment 1, examined memory interference effects at retrieval when the distracting tasks were presented in a different modality (auditorily) than the primary memory task (visually). Here we define modality as the manner in which a stimulus is presented to the participant, which in the case of words, can be auditorily through speakers or headphones, or visually presented on screen. Within each modality, ‘materials’ are defined as a specific class of stimuli, for example digits, words, scenes or faces, regardless of their orientation or presentation. Certain material sets can straddle two modalities, as is the case with words or digits, however faces are restricted to the visual modality. Lastly, within each class of materials, ‘processing’ is defined as the act performed with those materials, depending on task demands. Words for example, can be processed semantically when a task demands use of meaning, or phonologically when a task demands decisions about rhyming. As another example, and critically for the current work, faces can be processed in either a featural or a configural way, depending on the task requirements.

With this in mind, it seems obvious that very different processes would be required to visualize an auditorily presented letter relative to processing a visually presented face, the stimuli paired together in Experiment 1. To our knowledge, examination of the effect of DA at retrieval from 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, however, the best method of assessing a processing account is to compare interference patterns between DA conditions in which distracting tasks are presented within the same modality, and use the same set of materials, as the target task, but differ in terms of whether the processing requirements of the distracting task do or do not overlap with the target memory task.

Experiment 2

In Experiment 2 we compared the magnitude of memory interference from DA conditions at retrieval when the processing requirement in the distracting task did or did not overlap with that needed on the target memory task. Faces provide an ideal stimulus for such a paradigm as they can be processed in two different 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.

Previous work suggests that faces are visuo-spatial stimuli which 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. Thus, although featural-based processing plays a minor role in supporting memory for upright faces, retrieval is likely much more reliant on configural-based processing. Inverted faces however, are retrieved using featural processing, as configural processing is offset (Carbon & Leder, 2005; Yin, 1969).

The goal of this work was to determine first whether memory for faces was susceptible to interference from DA conditions at retrieval, and second, whether this interference pattern was influenced by the overlap in processing requirements between the target and distracting tasks in a DA paradigm. Two distracting tasks were crafted such that one required configural and the other featural processing. It was expected that both tasks would incur substantial costs to face memory performance (due to material-specific competition), though the configural distracting task would interfere more with memory for upright faces than the featural one. Conversely, it was expected that memory for inverted faces would suffer more when the distracting task required featural than configural processing. To test this hypothesis, in our DA featural (DAF) condition, distracting task faces were inverted, while in our DA configural (DAC) condition distracting task faces were upright (Goffaux & Rossion, 2006).

Previous research has shown that there is a limit to one's face processing ability, as peripheral presentation of distracting faces, or working memory loads of three faces can interfere with short-term memory for faces (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). Cheung and Gauthier's (2010) results suggest that processing of distractor faces leads to interference in the encoding of configural or holistic information about faces in a short-term memory paradigm, though no exploration of analogous effects within long-term memory has been done.

In our experiment, we predicted 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. Such a finding would support a processing-specific account of interference. Accordingly, the aim for Experiment 2 was to examine the influence of our simultaneously performed distracting tasks on memory for both upright and inverted faces.

Ruling out Distracting Task Difficulty

To ensure that any potential interaction in pattern of memory interference effects was not driven by differences in level of difficulty across distracting tasks, further data were collected. A continuous response time (CRT) tone classification task was performed simultaneously with the featural or configural distracting tasks, to gauge relative attention-demands of each. If one task was simply more difficult or attention-demanding than the other, differences in magnitude of interference with retrieval could appear. A CRT task was conducted such that performance was measured in a baseline condition and under dual-task conditions with each of our distracting tasks. Differences in difficulty or attentional demands on the featural and configural distracting tasks would be reflected in differentially impaired performance (i.e. slower time to classify tones, and fewer tones correctly classified), when performed concurrently. If, however, CRT performance was similarly affected by each distracting task, then there would be less reason to

believe that they differed in level of difficulty or resource requirements that could differentially affect memory.

Method

Participants.

Memory experiment. Forty-eight naïve undergraduate students (26 female) at the University of Waterloo completed the experiment³. 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.

CRT tone classification task. 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 memory task. Faces, again taken from the GUFID (Burton et al., 2010) 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 reserved 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 additional faces from the original set were blurred, to be used as ‘fillers’ during the FA memory condition.

Distracting tasks. For our featural distracting task, 60 faces were selected from the GUFID (Burton et al., 2010) such that half had light-colored eyes and half dark-colored eyes. All stimuli for the featural distracting task were inverted using ImageMagick software (ImageMagick Studio LLC, 1999-2013).

For our 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. In addition, a low pass filter (LPF) was applied to the distracting faces used in the DAC condition during recognition of inverted faces only, as others have suggested that this biases viewers more toward configural processing (Goffaux & Rossion, 2006).

CRT tone classification task. Low, medium, and high pitched tones were created using Audacity software (Mazzoni & Dannenberg, 2000). Each .wav file was 500 ms in length, and tones were randomly selected continuously until the face task was completed.

Procedure. Participants were randomly assigned to either the Upright or Inverted condition. For those in the Upright condition, faces in the recognition memory task were presented in the upright position, and for those in the inverted condition, faces for the recognition memory task were inverted. Stimulus presentation and response collection was controlled using E-prime v2.0 software (Psychology Software Tools Inc., Pittsburgh, PA) via an IBM computer, with a 17 inch monitor. Instructions were presented in English both on-screen and aloud by the experimenter. A practice phase was completed first, to familiarize participants with the tasks, followed by the experimental phase. The faces for each task were presented with a black bar either above or

below the image, to indicate which task was to be performed in reference to that face (see below for description).

Target recognition task.

Encoding. During each of the three encoding phases, participants were asked to study 15 images 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 of approximately one minute, participants completed the recognition task.

Retrieval. During each of the three retrieval phases, participants were shown 30 faces, one at a time (15 ‘targets’ and 15 ‘lures’), each with a black bar above it. Targets were the same photographs that participants had studied in the encoding phase. 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 as being from the immediately preceding study phase, and to refrain from responding if they did not recognize the face (see Figure 1 for experimental design).

Featural distracting task. For each trial, inverted faces were presented for 2000ms, one at a time, with a black bar underneath each (to denote that face as being the one requiring distracting task, rather than memorial, decisions) followed by a blank screen for 500 ms. Participants were asked to verbally 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”. Responses were recorded manually by the experimenter.

Configural distracting task. For each trial, upright faces were presented for 2000ms, one at a time, with a black bar underneath each (to denote that face as being the one requiring distracting

task, rather than memorial, decisions) followed by a blank screen for 500 ms. Participants were asked to verbally answer the following question for each trial: “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”. Responses were recorded manually by the experimenter.

CRT tone classification task. A group of naïve participants were asked to perform a task requiring classification of computer-generated tones as either low, medium, or high. For each trial, as soon as the participant had classified the tone, the next trial was immediately presented. If no response was given within 3 seconds, the next tone was presented. This task was performed alone (baseline), as well as under DA conditions with each of our distracting tasks. The distracting tasks consisted of verbal responses to 30 face stimuli, as indicated in the previous section describing each distracting task. Verbal responses and response times (RT) to distracting tasks were collected using a Serial Response box with voice onset relay. The duration of the baseline tone classification task duration was matched so that it took the same amount of time (1 minute 15 seconds) as the 30 trials of each distracting task.

Experimental Phase. After completing a practice phase, participants completed a baseline measure of one of the distracting tasks (i.e. the featural or configural distracting task performed alone). Following this, the memory conditions (three separate encoding-retrieval phases) were completed in counterbalanced order. The session ended with a baseline of the remaining distracting task.

The encoding phase for each of the three memory conditions was completed under full attention. Following this, participants performed retrieval (recognition memory task) either under FA, in which recognition was performed alone, or under each of the two DA conditions. The

DAF condition required completion of recognition concurrently with the featural distracting task, whereas the DAC condition required simultaneous completion of the configural distracting task. In both DA conditions, onset of the stimulus for each task was simultaneous, and participants were explicitly told that each task was equally important and to divide their attention equally between them.

Because stimuli for both tasks were presented visually in the DA conditions, a peripheral cue was required to indicate which face belonged to the respective tasks. That is, for each trial 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. The face requiring a memorial decision was denoted with a bar above it, and the face requiring a distracting task decision was denoted with a bar below it (see Figure 1). The location of the face (left or right) for the memory and distracting tasks was switched randomly on each trial to prevent the participant from developing a strategy of always performing one task first.

For clarification, the following is an example of how one participant completed the experimental paradigm. The participant began with the practice phase, then complete a baseline condition of the featural distracting task performed alone. Next, they studied 15 faces under FA, followed by recognition under FA. Next 15 novel faces were studied under FA, followed by the recognition task performed concurrently with the featural distracting task. Next, 15 novel faces were studied under FA, followed by one last recognition task, performed concurrently with the configural distracting task. Finally, the participant completed a baseline condition of the configural distracting task performed alone. Note that there were always two faces presented on screen for each recognition trial regardless of conditions. In the case of recognition in the FA condition, a blurred face image was presented alongside it to act as a place-filler, making the

visual demands of the FA condition the same as in the DA conditions in which another face was simultaneously presented. The only circumstance in which one solitary face was presented on the screen was during the encoding phases, and in the baseline distracting task conditions. In the DA conditions, each trial consisted of two distinct responses (button press and verbal yes/no) to each of the two different faces, whereas the FA condition required only a button press response.

Results

Recognition discriminability. A repeated measures ANOVA was conducted². Face Type (Upright or Inverted) was the between-participants factor, and Attention condition (FA, DAF or DAC) was the within-participant factor. There was a significant main effect of Face Type, $F(1, 46) = 16.78$, $MSE = .31$, $p < .001$, $\eta^2 = .27$, such that discriminability was higher for Upright than for Inverted faces. There was also a significant main effect of Attention, $F(2, 92) = 28.26$, $MSE = .38$, $p < .001$, $\eta^2 = .38$, and a significant Attention X Face Type interaction, $F(2, 92) = 8.63$, $MSE = .38$, $p < .001$, $\eta^2 = .16$. (See Table 1, Figure 2). To determine the source of the interaction, separate repeated measures ANOVAs were conducted for each Face type (Upright and Inverted).

Upright faces. 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, $F(2, 46) = 24.63$, $MSE = .41$, $p < .001$, $\eta^2 = .52$. Specifically, memory discriminability in the FA condition was significantly higher than in both the DAF, $F(1, 23) = 9.43$, $MSE = .96$, $p < .01$, $\eta^2 = .29$, and DAC, $F(1, 23) = 49.21$, $MSE = .96$, $p < .001$, $\eta^2 = .68$, conditions (See Figure 2). Crucially, results showed that memory discriminability was significantly lower in the DAC than in the DAF condition, $F(1, 23) = 16.53$, $MSE = .81$, $p < .001$, $\eta^2 = .42$, indicating that the configural distracting task interfered significantly more with memory for Upright faces than did the featural distracting task (See Table 1, Figure 2).

Inverted faces. 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, $F(2, 46) = 11.45$, $MSE = .36$, $p < .001$, $\eta^2 = .33$. Similar to Upright faces, memory for Inverted faces was significantly higher in the FA condition than in both the DAF, $F(1, 23) = 18.15$, $MSE = .89$, $p < .001$, $\eta^2 = .44$, and DAC, $F(1, 23) = 9.25$, $MSE = .89$, $p < .01$, $\eta^2 = .29$, conditions (See Figure 2). Opposite to the findings with upright faces, however, memory was poorer in the DAF than in the DAC condition, $F(1, 23) = 3.99$, $MSE = .61$, $p = .058$, $\eta^2 = .15$. Although this effect only approached significance, it suggests that for Inverted faces, the featural distracting task in the DAF condition interfered more with memory discriminability than did the configural distracting task in DAC. Our finding of a significant Attention X Face Type interaction is thus driven by the opposite pattern of discriminability results in the DA conditions for upright compared to inverted faces.

Distracting task performance. Data for the distracting task were analyzed similarly to Experiment 1, in order to determine whether any differences in the difficulty of the distracting tasks could be contributing to the pattern of memory results. Again, task performance was computed as the proportion of correct responses. A $2 \times 2 \times 2$ repeated measures ANOVA was conducted, with Face Type 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 Type, $F(1, 46) = 12099.69$, $MSE = .013$, $p < .05$, $\eta^2 = 1.00$, 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 Face Type 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 Type (Upright and Inverted).

Upright faces. There was a significant main effect of Attention, $F(1, 23) = 42.54$, $MSE = .004$, $p < .001$, $\eta^2 = .65$, with higher performance in Baseline than DA conditions, and Task, $F(1, 23) = 13.06$, $MSE = .002$, $p < .005$, $\eta^2 = .36$ such that performance was worse on the Featural than on the Configural task. The interaction between Attention and Task was, however, not significant, $F(1, 23) = 2.71$, $MSE = .004$, $p = .11$, $\eta^2 = .11$. Importantly though, under dual-task conditions, the distracting tasks did not differ in difficulty, $t(23) = .60$, $SE = .018$, $p = .55$.

Inverted faces. There was a significant main effect of Attention, $F(1, 23) = 31.97$, $MSE = .005$, $p < .001$, $\eta^2 = .58$. However, the main effect of Task, $F(1, 23) = .16$, $MSE = .003$, $p = .69$, $\eta^2 = .01$, as well as the interaction between Attention and Task, $F(1, 23) = .70$, $MSE = .003$, $p = .41$, $\eta^2 = .03$, were not significant (See Table 2).

CRT performance. As outlined above, an additional exploration of distracting task difficulty was undertaken to rule out this critical confound. To index task difficulty, a tone classification task was performed alone, and concurrently with each of the distracting tasks. If one distracting task was more difficult than another, one would expect that these would be reflected in larger performance reductions on the tone classification task. Below we unpack tone classification performance⁴ and associated distracting task performance (accuracy, response times).

Proportion Correct. A repeated measures ANOVA was conducted using proportion of tones correctly classified as a dependent variable. Condition (baseline, featural, configural, LPF configural) was included as a within-participants factor. 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 Table 3).

Distracting Task Performance. Proportion correct on the distracting tasks 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.

Baseline. The main effect of Task, $F(2, 46) = 14.38$, $MSE = .008$, $p < .001$, $\eta^2 = .38$, was driven by participants responding correctly to a higher proportion of faces in the configural task relative to both the featural task, $t(23) = 4.94$, $SE = .019$, $p < .001$, and the LPF configural task, $t(23) = 6.65$, $SE = .02$, $p < .001$, which were not significantly different from one another, $t(23) = 1.07$, $SE = .035$, $p = .29$.

DA. The main effect of Task was not significant, $F(2, 46) = 1.74$, $MSE = .015$, $p = .19$, $\eta^2 = .07$. (See Table 3 for means).

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

Baseline. The main effect of Task, $F(2, 46) = 49.62$, $MSE = 5034.01$, $p < .001$, $\eta^2 = .68$, was driven by faster response times in the configural task relative to both the featural task, $t(23) = 3.77$, $SE = 17.44$, $p < .005$, and the LPF configural task, $t(23) = 8.08$, $SE = 22.13$, $p < .001$. Response times for the featural task were also significantly faster than for the LPF configural task, $t(23) = 8.10$, $SE = 13.97$, $p < .001$.

DA. The main effect of Task, $F(2, 46) = 4.05$, $MSE = 3717.40$, $p < .05$, $\eta^2 = .15$, was driven by faster response times in the featural than in the LPF configural task, $t(23) = 2.65$, $SE = 16.92$, $p < .05$. All other comparisons were not significant (See Table 3 for means).

Discussion

Experiment 2 showed that the magnitude of interference under DA conditions at retrieval was different depending on whether the target face requiring the memorial decision 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 discriminability 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. Our results provide support for the idea that memory interference at retrieval results from competition not only for similar materials in the concurrent tasks (as suggested by Fernandes & Moscovitch, 2000), but also from competition for common processing resources.

We set out to determine whether a processing-specific account was more suitable than a material-specific one for explaining the effects of DA on retrieval. As an interim conclusion, it seems that while material-specificity is relevant (given that substantial memory deficits were incurred as a result of both DA conditions) processing-specificity may have a greater relative

contribution to the observed pattern of memory performance. To rule out distracting task difficulty as an alternative explanation for the observed pattern of memory interference in this experiment, extensive analyses were conducted to gauge 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.

We also analyzed performance on the distracting tasks themselves, when performed concurrently with the recognition task. Although there were some marginal differences between tasks, the differences were in the opposite direction one would expect if it was the case that our effects were driven by task difficulty. That is, the featural task was slightly more difficult than the configural one, as indexed by a lower proportion of correct responses (similarly, the auditory CRT data showed that accuracy was lower when performed concurrently with the featural as compared to the configural distracting task). The expected outcome, if task difficulty was driving our effect, would be that memory performance would be disrupted more by the featural task, which is precisely the opposite of what our data on memory for upright faces showed. Response times for the featural task, performed concurrently with the CRT 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 2. Given that the predicted effect was still clearly displayed, the distracting task and CRT results bolster the argument of the current work.

Combined Analysis: Experiment 1 and 2

In order to determine the relative contributions of material-specific and processing-specific interference, data from Experiments 1 and 2 were combined to allow a comparison of the three different classes of divided attention conditions, including (1) Neither material or processing-specific overlap (Experiment 1: DAP and DAI), (2) Material-specific overlap alone (Experiment 2: DAF with upright faces, DAC with inverted faces), and (3) Both material and processing-specific overlap (Experiment 2: DAC with upright faces, DAF with inverted faces).

Results

For each of these three classes of distracting task, a proportional score for decline from full attention performance was computed (calculated as $(FA d' - DA d')/FA d'$). These proportional decline scores were compared using one-way ANOVA with Type of overlap with the target memory task (None, Material-specific alone, Material and Processing-specific overlap) as a between-participants variable. There was a significant main effect of Type of Overlap, $F(2, 141) = 4.87$, $MSE = .18$, $p < .01$, $\eta^2 = .07$, driven by significantly higher interference in the case of distracting tasks which overlapped both in terms of material and processing-specificity ($M = .43$, $SE = .06$, $CI_{95} [0.31, 0.56]$) relative to distracting tasks which competed for neither ($M = .22$, $SE = .05$, $CI_{95} [0.11, 0.32]$), $t(94) = 2.60$, $SE = .08$, $p < .05$, or when the distracting task overlapped only in terms of materials ($M = .19$, $SE = .06$, $CI_{95} [0.07, 0.31]$), $t(94) = 2.68$, $SE = .09$, $p < .01$. Distracting tasks competing for only materials did not lead to a proportional decline in memory that differed significantly from distracting tasks that did not overlap with the target stimuli in the memory task for either materials or type of processing, $t(94) = .30$, $SE = .08$, $p > .05$, *ns*. This pattern of results is illustrated in Figure 3. For comparison we also show the proportional decline observed on recognition tasks under divided attention conditions with

distracting tasks from other studies (Baddeley et al., 1984, Craik et al., 1996, Fernandes et al., 2005). In Figure 3, data are displayed in terms of proportional decline in accuracy, rather than discriminability, relative to FA, to facilitate comparison with previous work.

Discussion

Results indicate that when concurrent tasks under DA during retrieval overlap in terms of materials alone (Experiment 2: DAF with upright faces, DAC with inverted faces) interference is similar in magnitude to when the concurrent task has no material or processing-specific overlap with the stimuli in the target memory task. The largest declines in memory performance occurred when the concurrent tasks required the same processing resources, and also used the same material set as that in the target recognition task.

General Discussion

Past research suggests that retrieval interference occurs under DA conditions due to material-specific overlap between concurrent tasks. We examined the feasibility of a processing-specific account of retrieval interference. We showed that competition between the memory and distracting task for processing-specific resources (Experiment 2: Upright faces: DAC; Inverted faces: DAF) lead to the greatest magnitude of interference with recognition memory (42% decline). Counter to previous work (Barnes & Dougherty, 2007; Ciaramelli et al., 2009; Clarke & Butler, 2008; Fernandes et al., 2004; 2005; 2006; Fernandes & Moscovitch, 2000; 2002; 2003; Wais et al., 2010; 2012), material-specific competition alone (Upright faces: DAF; Inverted faces: DAC) was no different in terms of cost to memory performance (20 % decline) than was competition from distracting tasks that interfered with neither materials nor processing (Experiment 1: DAP and DAI, 19% decline).

While we did show that face memory was sensitive to interference from face-based distracting tasks, the design of Experiment 2 also allowed us to explore the possibility of a crossover interaction, in which a configural distracting task would interfere more than a featural one with memory for upright faces, but less with memory for inverted faces. Results showed this interaction, such that the magnitude of interference was modulated by whether the type of processing required by the concurrently performed tasks overlapped. Critically, our combined analyses provided surprising evidence to suggest that when only materials were common across the memory and distracting tasks, the degree of interference with memory for faces was minimal, and did not differ significantly from DA conditions in which both the materials and processing were dissimilar to that in the target memory task. Researchers claimed that memory for words was impaired in previous studies because the simultaneously performed distractor task also required word processing (Barnes & Dougherty, 2007; Ciaramelli et al., 2009; Clarke & Butler, 2008; Fernandes et al., 2004; 2006; Wais et al., 2010; 2012). Our findings are not consistent with such a conclusion, and instead support a processing specific account of memory interference at retrieval.

Previous work in short-term memory and attention had shown that successful performance on two simultaneously completed tasks may depend on the overlap, or relation, between the processing used in each (Pellegrino, Siegel & Dhawan, 1976; Wickens, 2008). Such processing-specific interference is in line with the Baddeley and Hitch (1974) framework of working memory as a multicomponent system. According to this framework, working memory can be broken down into constituent parts, each of which processes specific classes of stimuli and is sensitive to suppression from different distracting tasks or conditions. Thus the current study not only expands on initial findings of processing-specific competition (Fernandes & Guild, 2009,

Fernandes et al., 2013), but also supports the generality of a processing-specific account for understanding how DA affects both short and long term memory similarly. Based on our current study, the magnitude of episodic memory interference, for faces at least, appears to be due to processing-rather than material-specific competition between concurrent tasks. It is important that future research determine to what extent each plays a role, and whether the findings here are applicable to memory for other types of stimuli. 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. Specifically, if processing overlap can account 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 utilizes a specific pool of resources based on the type of processing required. When these resources are depleted by a distracting task (which requires the same type of processing), retrieval will falter. Given that in everyday life, we are prone to multi-tasking, it is critical to be aware of the situations that allow memory to thrive, and conversely break down.

One corollary from the finding that it is competition for processing, rather than material-specific resources that determines dual-task interference, is an alluring possibility for bolstering memory. If we know that competition for processing-specific resources negatively impacts successful retrieval, it is possible that adding another level of processing to a memory trace via some subject-performed task at encoding, could afford some protection to the memory, providing an additional processing type to fall back on when one is degraded through interference. For example, if one performs an action associated with to-be-remembered information, an iteration of the enactment effect (Guttentag & Hunt, 1988), one might expect that they will have an

additional motor trace through which they can later access the memory if the original trace suffers from dual-task interference.

Another goal of the study was to examine memory for visuo-spatial stimuli, which is rarely done in dual-task research. Most previous studies of DA effects on episodic retrieval examined memory for verbal stimuli. Only two examined memory for visuo-spatial information, though one used unfamiliar, lab-created stimuli (grids; Fernandes & Guild, 2009), and the other used Chinese characters (Fernandes et al., 2013) which were uncommon for some participants, but familiar verbal material for others. Thus the generalizability of reported effects of DA at retrieval to visuo-spatial material could be questioned. Faces were chosen as the stimuli for the present study by virtue of having an exposure frequency comparable to that of words, but also because they engage two different types of processing (Goffaux & Rossion, 2006, Rhodes, 1988). In both Experiment 1 and 2, memory discriminability for studied faces was reduced under DA, relative to FA conditions, with distracting tasks that used letter or face stimuli. The interference was most pronounced when both tasks used the same materials and the same type of processing. This finding supports a processing-specific account of interference with memory retrieval, at least for visuo-spatial stimuli such as faces.

Our results also contribute to the existing knowledge on the ways in which faces can be processed. Because we were able to find 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 towards a specific means of processing faces, providing a paradigm to tease these apart.

Future research should expand on the current findings to determine whether processing-specific interference can explain all DA effects at retrieval. We did show that interference occurred between two tasks using the same materials and processing, but because our study only used one type of material (faces), we cannot make conclusions about memory in general. We showed a differentially large effect when processing requirements overlapped, suggesting that competition for processing resources is an important contributor to interference; such a finding suggests an amendment is necessary to a material-specific explanation of DA effects at retrieval.

Conclusion

Overall, we showed that episodic memory for faces is sensitive to interference, even from distracting tasks that use different materials (Experiment 1), a finding at odds with a purely material-specific account of DA effects on retrieval. More importantly, we showed that the magnitude of interference was modulated depending on whether the memory and distractor tasks had overlapping processing requirements (Experiment 2). Importantly, we showed that when concurrent tasks overlap in terms of materials, interference is similar in magnitude to when the concurrent task has neither material nor processing-specific overlap with the stimuli in the target memory task.

Such a finding suggests that a material-specific account is not necessary or sufficient to explain dual-task effects on memory for faces. Our findings support and extend a processing-specific account of dual-task interference on episodic retrieval, and suggest that, for faces, it is superior to a material-specific account.

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Table 1

Mean Hit Rate (H), False Alarm Rate (F), Accuracy (H-F) and Discriminability (d') in Experiment 1 and each Face Type in Experiment 2, under Full Attention and Divided Attention (DA) Conditions Requiring Phonological or Imagery Decisions to Distracting Letters or Featural or Configural Decisions to Distracting Face Stimuli (95% Confidence Intervals in Parentheses)

Experiment, condition	H	F	H-F	d'
1: Upright faces				
Full attention	0.80 (0.06)	0.10 (0.04)	0.70 (0.07)	2.38 (0.32)
DA phonological	0.70 (0.06)	0.14 (0.05)	0.56 (0.09)	1.81 (0.32)
DA imagery	0.75 (0.07)	0.16 (0.05)	0.59 (0.10)	1.93 (0.40)
2: Upright faces				
Full attention	0.86 (0.04)	0.05 (0.02)	0.81 (0.05)	2.73 (0.26)
DA featural	0.77 (0.06)	0.12 (0.04)	0.65 (0.08)	2.12 (0.29)
DA configural	0.62 (0.08)	0.17 (0.05)	0.45 (0.11)	1.44 (0.36)
2: Inverted faces				
Full attention	0.82 (0.05)	0.21 (0.05)	0.61 (0.07)	1.88 (0.27)
DA featural	0.69 (0.05)	0.33 (0.08)	0.37 (0.10)	1.06 (0.31)
DA configural	0.81 (0.04)	0.36 (0.07)	0.46 (0.08)	1.38 (0.26)

Table 2

Mean Distracting Task Performance in Experiment 2 for Each Face Type, under Baseline and Divided Attention, for Each Task Condition (95% Confidence Intervals in Parentheses)

Face Type	Baseline		Divided Attention	
	Featural	Configural	Featural	Configural
Upright faces	.93 (.03)	.98 (.01)	.87 (.03)	.88 (.04)
Inverted faces	.92 (.02)	.91 (.02)*	.83 (.03)	.83 (.04)*

* Distracting faces were low-pass filtered

Table 3

Means and 95% Confidence Intervals for Performance Measures on the Continuous Reaction-Time (CRT) and Distracting Tasks Under the Full Attention Baseline Condition and Under Divided Attention (DA) Conditions

Condition and Task	CRT task					
	<u>Correct Responses</u>		<u>Proportion Correct</u>		<u>Reaction Time</u>	
	M	CI	M	CI	M	CI
Baseline CRT	67.40	11.96	0.75	0.07	875.46	63.19
DA						
Featural	36.58	8.59	0.52	0.09	1078.62	93.08
Configural	34.37	8.58	0.50	0.09	1074.28	118.99
LPF configural	36.16	8.46	0.52	0.08	1050.97	87.16
	Distracting task					
	<u>Proportion</u>		<u>Reaction Time</u>			
	M	CI	M	CI		
Baseline						
Featural	0.87	0.04	813.71	41.75		
Configural	0.97	0.03	747.99	48.87		
LPF configural	0.84	0.05	926.79	42.46		
DA						
Featural	0.77	0.05	1083.61	46.53		
Configural	0.75	0.08	1086.52	41.75		
LPF configural	0.70	0.07	1128.38	37.77		

Note: LPF = low pass filtered

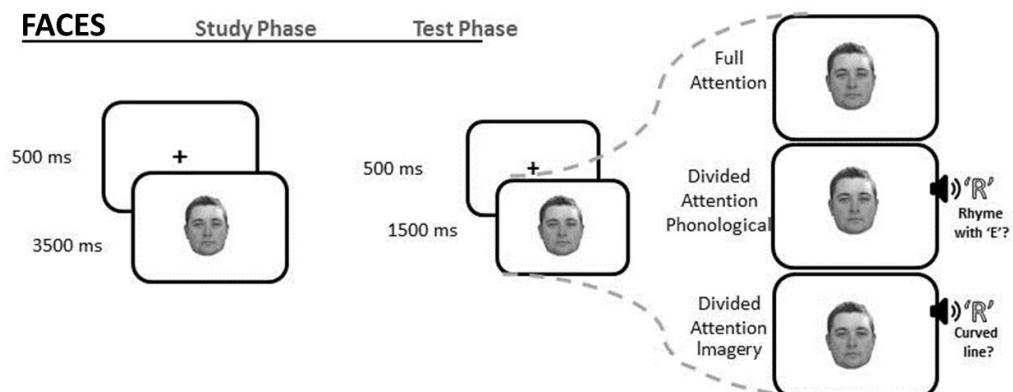
Figure Captions

Figure 1. Sample trials for the face recognition task under full attention (FA) or concurrently with a distracting task requiring either phonological (DAP) or imagery (DAI) processing (Experiment 1) and for recognition of upright or inverted faces under FA or concurrently with a distracting task requiring either featural (DAF) or configural (DAC) processing (Experiment 2).

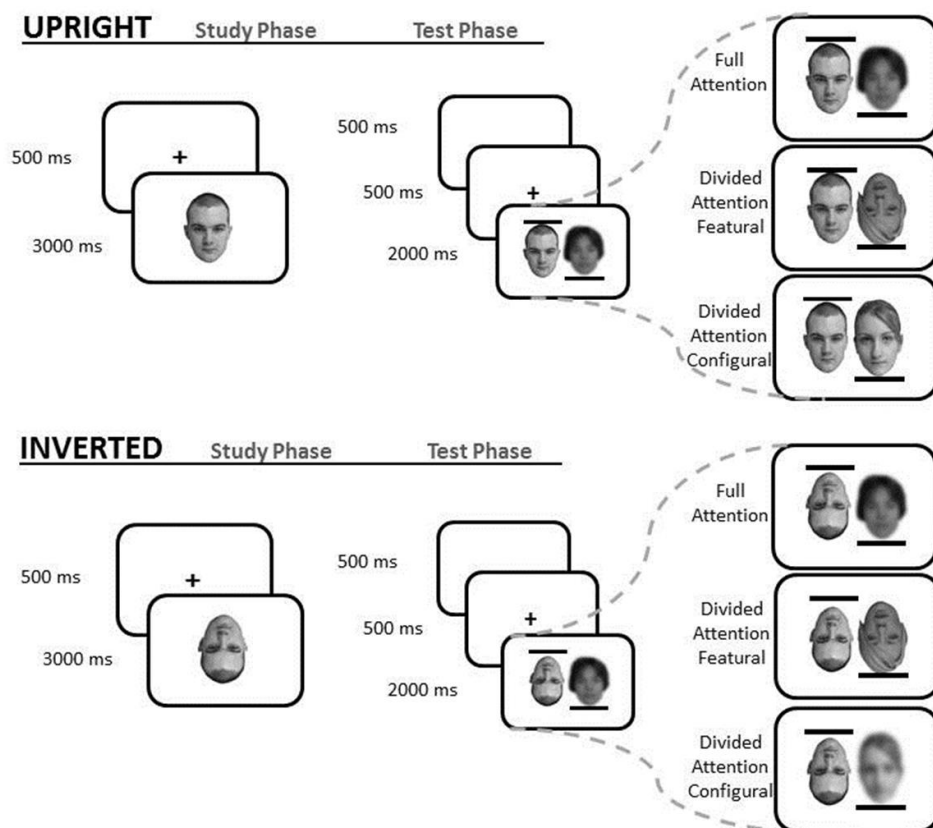
Figure 2. Memory discriminability for upright versus inverted faces under full attention (FA) or concurrently with a distracting task requiring either featural (DAF) or configural (DAC) processing. Error bars are 95% confidence intervals.

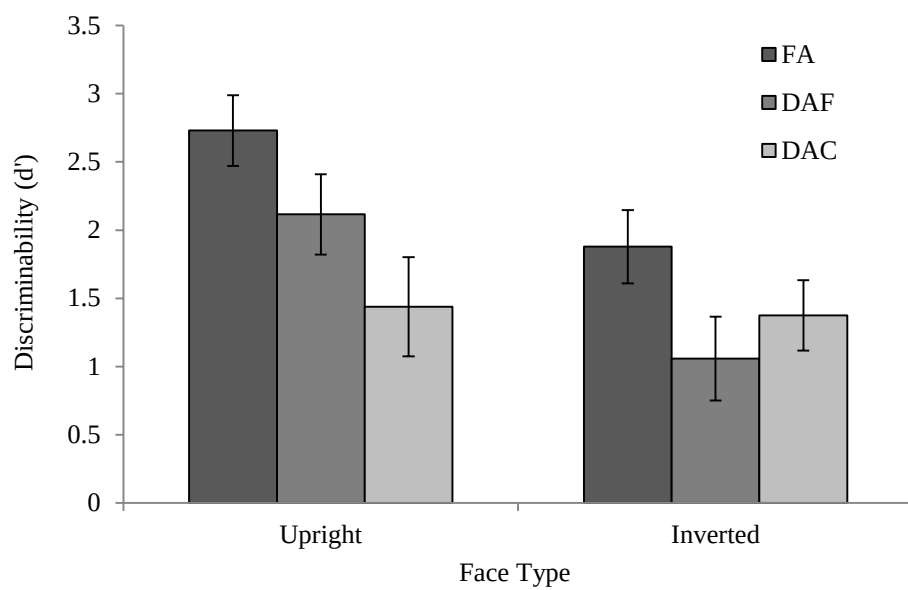
Figure 3. Proportion decline in memory accuracy from full attention (FA), when completing recognition with various distracting tasks. On the left are relevant previous results exploring this phenomenon in memory for words, while on the right are the experiments from the current work in memory for faces. Bar color indicates whether the distracting and memory tasks overlapped in terms of neither processing nor material-specificity (white), material-specificity only (grey), or both material- and processing-specificity (black). Error bars are 95% confidence intervals.

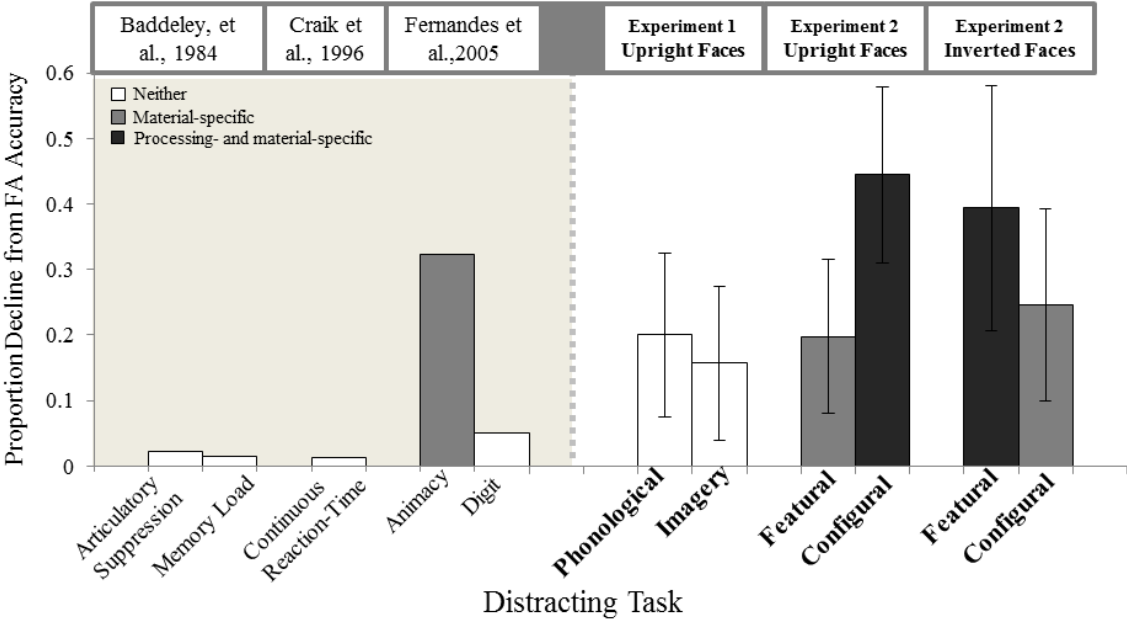
EXPERIMENT 1



EXPERIMENT 2







Footnotes

¹ An a priori threshold was set to exclude participants scoring below 0.4 in accuracy. With scores this close to floor, any further reduction from a DA condition is unlikely to be observed, thereby preventing a reliable estimate of interference effects. One participant fell below this threshold and a new participant was run in their place. The excluded participant was greater than 2.0 units of standard deviation below the final sample's mean for accuracy.

² The assumption of sphericity was tested using Mauchly's test for all ANOVAs, and the Greenhouse-Geisser corrections were applied when warranted.

³ As in Experiment 1, an a priori threshold was set to exclude participants scoring below 0.4 in accuracy. 14 participants fell below this cutoff and new participants were run in their place. To be conservative, analyses were also conducted with these participants included, and the results followed the same pattern as reported. The excluded participants were greater than 2.0 units of standard deviation below the final sample's grand mean for accuracy.

⁴ Tone classification data were also analyzed for the raw number of tones correctly identified, as well as response times. These data followed the exact same pattern, such that baseline performance was better and faster than all dual-task conditions, which were not different from one another (See Table 3 for means).