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DEPARTMENT OF PSYCHOLOGY

The Link Between Processing Faces and Words

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ABSTRACT

Recent research has suggested that reading words and reading faces share similar neural underpinnings (Behrrmann, 2011, 2012; Kelly, 1989). The line of research in this paper aims to examine behavioral evidence linking these two abilities. As part of this study, we had participants fill out a number of related measures including: The Cambridge Face Memory Test (Duchaine and Nakayama, 2006) to measure facial recognition and identify prosopagnosia, the Diagnostic Analysis of Nonverbal Accuracy (Duke and Nowicki, 1994) to measure nonverbal social expressions, the Rapid Automatized Naming (Denckla and Rudel, 1976) to measure verbal processing speed, and the Test of Word Reading Efficiency (Torgeson, Wagner, & Rashotte, 1999) to measure reading accuracy and fluency and identify dyslexia. We also included an experimental task that aimed to measure behavioral impairments in individual's word/facial processing via neural habituation. We predicted that participants would have slower reaction times when processing words and faces following the habituation of faces and words, respectively. Unfortunately, our neural adaptation task failed to yield any evidence for habituation. However, the four standardized assessments yielded strong evidence for the link between face and word processing such that the Cambridge Face Memory Test (CFMT) was positively correlated with the Rapid Automatized Naming (RAN), and both subsets of the Test of Word Reading Efficiency (TOWRE). These results are consistent with evidence for shared neural substrates underlying face and word processing and provide new perspectives for future research examining the two abilities in conjunction with one another.

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Introduction

Everyday we interact with people visually and socially, resulting in the processing of new and old faces. Moreover, on a daily basis, we read and interpret words, sentences, and paragraphs. Depending on the context, these two processes may occur dependently or independently of one another. However, recent research suggests that the processes of encoding faces and reading words share similar neural underpinnings. Thus, in the present study we aim to examine whether processing words and faces actually influence one another.

Generally, an accepted view obtained through neuroimaging and neuropsychological investigations depicts the right hemisphere to be associated non-verbal processes, whereas the left hemisphere is responsible for verbal processes. The right hemisphere operates to control functions such as facial recognition and facial processing, whereas the left hemisphere is primarily responsible for controlling language-associated mechanisms such as the processing of words. However, in an experiment where subjects were presented with three faces and asked to distinguish if the first face matched the second or third, several left frontal regions were activated during the nonverbal task (Grady et al., 1995). Although the left hemisphere activations were inferior to the right hemisphere, this finding suggests that the neurons in the left and right hemispheres may have mild overlaps (Kelley, 1998).

In addition, further studies have also suggested that the neurons associated with the right and left hemispheres are more dependent on one another than previously accepted. Rather than associating specific brain regions with specific functions, an alternative view suggests a single region that directs many different tasks, or a single task that is mediated by different regions (Behrmann & Plaut, 2011). Studying the ventral visual cortex and its organizational structure, it has been found that prosopagnosics have mild but reliable word recognition deficits and pure alexics also have mild but reliable face recognition deficits (Behrmann & Plaut, 2012). These findings suggest that there are overlaps within the neural underpinnings responsible for both face and word processing. More specifically, damage to one hemisphere directly affects the processes that the parallel hemisphere is primarily responsible for.

The dependence of the two hemispheres has been further supported in developmental studies which focused on the developmental processes related to both face processing and word processing between children and young adults (Dundas et al., 2012). In this study, it was found that in regard to development, word lateralization precedes face lateralization. In addition, it was found that reading comprehension scores predicted the degree of face lateralization which suggests that the left and right hemispheres do not develop independently (Dundas, et al., 2012).

The dependency of the right and left hemispheres in the developmental process can be further explored in studying the link between processing words and processing faces. The present study aimed to 1) examine the relationship between word and face processing using highly standardized performance measures, and 2) examine whether habituating to one type of stimulus (i.e., words) can disrupt the processing of the other (i.e., faces). We chose a computer-based experiment in which participants habituated to three categories of stimuli, i.e., faces, words, and objects. After attempting a habituation manipulation to one category of stimuli, we then presented participants with a different set of stimuli (either words, faces, or objects) and instructed to indicate whether or not the presented stimuli on the left and right sides of the screen were the same or different.

The habituation tasks were designed to replicate the novel flashed face distortion effect discovered by Tangen, Thompson, and Murphy (2011). While studying face adaptation, Tangen and colleagues noticed that when flashing 4-5 faces per second bilaterally with a fixation point on the center of the screen, the faces presented on the left and right sides of the fixation point became caricatures of themselves, appearing slightly deformed. The fast pace that the faces were presented, along with the effect of setting the faces up so that the eyes were horizontally and vertically aligned, produced this effect. Certain features, such as a large forehead, were extenuated to appear even larger; other features, such as a thin nose, simultaneously began to appear even slimmer (Tangen et al, 2011). Although it remains unknown why this illusion occurs, Tangen et al. speculated it may have to do with neural habituation. Thus, we used this same face flashed distortion technique in an attempt to habituate participants to objects (i.e., radios), words, and faces by exposing them to flashing stimuli for 30-seconds, with the faces/objects/words changing every 250 ms; thus 4 sets of faces/objects/words were flashed per second, as was seen in the flashed face distortion adaptation.

We predicted that after habituating to words and faces, participants will be slower while processing faces and words respectively. If the habituation task was successful, participants should be slower to words following words, faces following faces, and objects following objects. Since habituation lasts approximately 12 seconds, we estimated that participants would still be experiencing the habituation throughout the experimental task testing their speed in processing and reading words, faces, and objects (Thompson & Spencer, 1996). Objects were used as a control stimulus to ensure that any processing impairments are due to habituation and not a confounding factor, such as simply fatigue.

We also administered four standardized tests that focus on face and word processing. The Test of Word Reading Efficiency (TOWRE) was administered to the participants, which is a standardized assessment to identify participants with dyslexia. This test consists of two subtests. In subtest I, Sight Word Efficiency, participants read real-words for 45-seconds, and; in Subtest II, Phonemic Decoding Efficiency, participants read pseudo-words for 45-seconds (Torgeson, Wagner, & Rashotte, 1999). It has been suggested that dyslexia is due to a "double-deficit hypothesis" which proposes that phonological deficits and naming-speed deficits are separate causes of reading impairments (Wolf and Bowers, 1999). Thus, we gave participants a short version of the Rapid Automatized Naming test, which times participant's speed in naming aloud letters. We also administered the Cambridge Face Memory Test (CFMT) to identify participants with prosopagnosia. Further, since the Diagnostic Analysis of Nonverbal Accuracy (DANVA) have shown to correlate with face memory in the past (Franklin & Adams, 2010; Palermo et al., 2013), we included it for future use on how verbal and nonverbal face processing relate to one another.

Methods

<u>Participants</u>

Undergraduate students taking introductory Psychology courses at the Pennsylvania State University (N=73, 51 females, 22 males) received extra course credit to participate in this study.

Four participants (2 females, 2 males) with CFMT results that fell 2 SD below the mean (*M* = 77.04), a level typically associated with prosopagnosia were dropped (Bowles, et al., 2009). Further, two participants (both females) with TOWRE (subtest I and II averages) results that fell 2 SD below the mean (*M* = 73.68), a level typically associated with dyslexia were also dropped from analysis (Thambirajah, M.S., 2010). This left a total of 67 participants in the analyses (47 females, 20 males).

<u>Materials</u>

The experimental part of the study consisted of three sets of stimuli: faces, words, and objects. The faces were compiled from face databases (Ebner, N, 2008; Minear, M. & Park, D.C., 2004). Since our subjects consisted of college students, we decided to keep the faces in-group by using only young faces. To induce the flashed face distortion effect described in the introduction, the faces were aligned so that the eyes matched up vertically and horizontally for each template of faces (Tangen, 2011). By aligning the faces in this position, and flashing 4 faces per second on the screen, the faces began to adopt a caricatured-type of illusion suggesting face adaptation (Tangen, 2011).

The words stimuli were based on the study conducted by Plaut & Behrmann (2011). In their study, three-letter words were chosen with differences in the central vowel to embody critical differences and place high demand on neural functioning (Behrrmann & Plaut, 2011). In the present study, we used trigrams with small differences as well. The words used were either phonologically or visually similar (i.e., CAT-FAT). All words were presented in uppercase Times New Roman 80-point font in black on a white background.

Lastly, for the habituation of objects, 120 different pictures of radios were collected and paired to form 60 separate templates. We chose radios as the stimuli for objects because, like faces and words, people are, to a large extent, familiar with radios. The radios consisted of both modern and old-fashioned radios.

All stimuli (radios, objects, and faces) were black and white as shown in Figure 1.

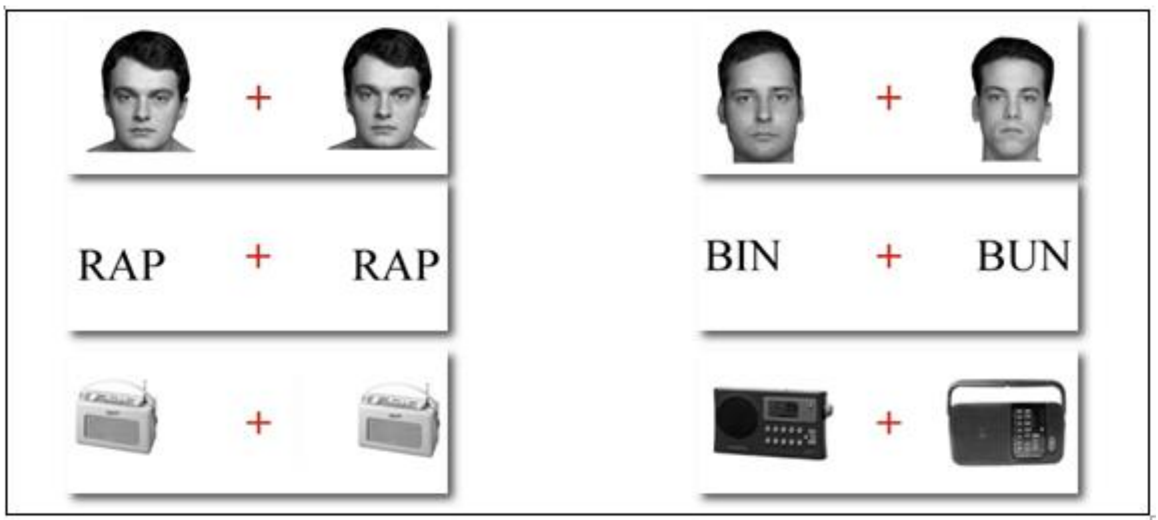

Figure 1. Experimental Study Stimuli Examples

Examples of the templates presented for faces, words, and objects stimuli in the habituation and same/different events. Each habituation task consisted of 120 templates changing ever 250 ms. For each trial, the processing condition event (indicating whether the stimuli was same/different) consisted of 20 same and 20 different randomized templates of radios, words, and faces.

In addition to the nine-block experimental task, four additional standardized tests were administered to participants including:

1. **The Cambridge Face Memory Test** (CFMT): This is a 72-item test that measures the ability of an individual to memorize and identify faces (Duchaine and Nakayama, 2006). One of the goals of the present study is to determine whether reading impairs face memory and emotion processing. This is a widely used and standardized test of prosopagnosia.
2. **Diagnostic Analysis of Nonverbal Accuracy** (DANVA): This is a 24 item test that measures individual differences in the accuracy of sending and receiving nonverbal social information (Duke and Nowicki, 1994). The DANVA consists of adult faces, males and females, expressing either happy, anger, fearful, or sad emotions. The test measures the accuracy of nonverbal processing of emotions.
3. **The Rapid Automatized Naming** (RAN): This test measures how fast an individual can name aloud objects, pictures, and letters (Denckla and Rudel, 1976). For the purpose of our study, only the letters (test 4) were presented.
4. **The Test of Word Reading Efficiency** (TOWRE): This is a standard test of dyslexia that has two subtests, each take 45-seconds: the Sight Word Efficiency Test, which assesses the number of words that can be accurately pronounced, and the Phonetic Decoding Efficiency subtest, which measures the number of printed pseudo-words participants can pronounce (Torgeson, Wagner, & Rashotte, 1999).

Procedure and Design

Four participants at a time were seated in the classroom, and each completed the entire study in a single, one-hour session. Participants began the study in front of computers where they were instructed to first complete the experimental nine-block task. The experimental task consisted of a 3(stimuli: faces, words, objects) x 3(stimuli: faces, words, objects) with-in participant factorial design. Upon beginning the study, participants were instructed to keep their eyes focused on the fixation point in the center of the computer screen for the duration of the study. The fixation point consisted of a red cross that remained in a consistent spot on the computer screen throughout the study. The overall study was broken up into nine blocks with two conditions. The first condition was always habituating to a stimuli, and the second condition was processing a different set of stimuli by indicating whether or not the visual presented on the left and right sides of the screen were the same or different. In each block the habituation task consisted of either faces, words, or objects being flashed on the left and right sides of the computer monitor for 250 ms for a total of 30 seconds. Following habituation, participant's were then presented with the experimental trial which consisted of either objects, words or faces that were either the same or different on the left and right sides of the monitor. During the experimental trial, participants were prompted to indicate whether the faces, words, or objects presented were the same or different by pressing the "1" key on the keyboard for same and the "3" key on the keyboard for different. The keys were labeled "s" and "d" respectively.

There were two versions of the task so that the blocks were distributed randomly amongst participants. The blocks for versions 1 and 2 were as follows:

Table 1. Block Order Versions 1 and 2 of Experimental Task

Version 1 of nine-block Experimental Test.			*Version 2 of nine-block Experimental Test.*		
Block	Habituation	Same/Different Task	Block	Habituation	Same/ Different Task
1	Objects	Words	1	Words	Objects
2	Words	Faces	2	Faces	Faces
3	Objects	Objects	3	Faces	Objects
4	Faces	Words	4	Words	Words
5	Objects	Faces	5	Objects	Faces
6	Words	Words	6	Faces	Words
7	Faces	Objects	7	Objects	Objects
8	Faces	Faces	8	Words	Faces
9	Words	Objects	9	Objects	Words

Following the experimental task, participants completed the CFMT and DANVA. The distribution of the CFMT and DANVA were counterbalanced among participants according to the version of the experimental task that the participant completed (see Table 1). Participants who received version 1 of the experimental task were given the CFMT and then the DANVA, and participants who received version 2 were given the DANVA prior to the CFMT.

Upon completion of the DANVA, CFMT, and experimental task, as a filler task participants completed a questionnaire that was used in a past Honor’s Thesis at the Schreyer Honors College (Barret, J., 2012). The questionnaire instructed participants to write down a short synopsis of a negative life event from their past and answer questions consisting of their emotional state after the event. This questionnaire was intended to keep participant's occupied while waiting to complete the TOWRE and RAN test, which was run individually in a separate room They were told their answers to the questionnaire would be used as pilot data for future studies.

In order to administer the TOWRE and RAN test, participants were brought one-by-one into a different classroom where a research assistant greeted them. In approximately 5 minutes, participants completed TOWRE (Sight Word Efficiency & Phonemic Decoding Efficiency) task and the RAN (Test 4: Letters) test. The research assistant marked participant's raw scores on paper for the RAN and Sight Word Efficiency tasks and recorded participant's responses on a laptop for the Phonemic Decoding Efficiency task.

Results

Experimental Task

A 3 (passive viewing block: face, object, word) X 3 (experimental task: face, object, word) repeated measures ANOVA revealed a significant main effect for passive view block, $F = 16.614$, $p < .001$. Responses to all trials- faces, objects, and words; were faster after exposure to the face habituation event. A significant main effect for experimental tasks, $F = 31.028$, $p < .001$, such that participants were faster at identifying the same/different objects than faces or words, regardless of the preceding habituation stimuli. There was also a significant interaction, $F = 18.156$, $p < .001$, between the preceding habituation block and experimental reaction time (see Figure 2).

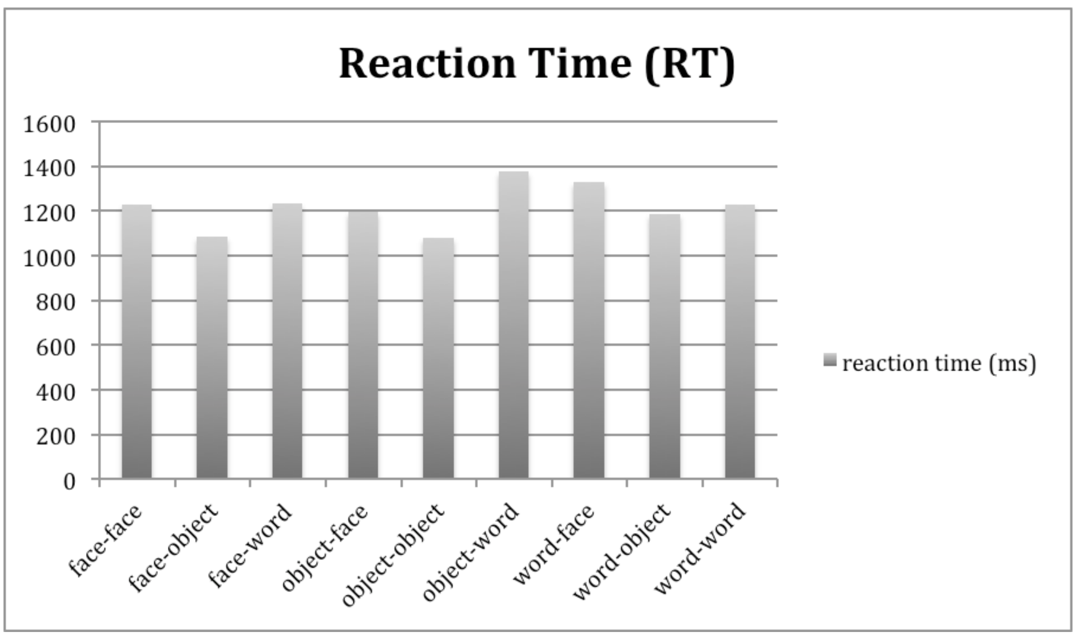

Figure 2. Participant Reaction Times

Participants average reaction times during the same/different task for each experimental block.

To explicate the interaction, we ran one-way ANOVAs, followed by paired sample t-tests separately for each experimental task: words, faces, and objects.

Face task:

A one-way within subjects ANOVA was conducted to compare the effect of habituation on reaction time during the same/different task for faces. There was a significant effect on reaction time for perceiving faces, $F(2, 65) = 16.03$, $p < .001$. To examine what was driving this effect, three paired samples t-tests were used to make post hoc comparisons between conditions. There was no significant difference in reaction time between the faces following faces condition ($M = 1222.17$, $SD = 478.05$) and faces following objects condition ($M = 1191.55$, $SD = 453.49$); $t(66) = 1.26$, $p > .2$. There was a significant difference in reaction time between the faces following faces condition ($M = 1222.17$, $SD = 478.05$) and the faces following words condition ($M = 1323.85$, $SD = 513.02$); $t(66) = -2.74$, $p > .005$. There was a significant difference between the faces following objects condition ($M = 1191.55$, $SD = 453.49$) and faces following words condition ($M = 1323.85$, $SD = 513.02$), $t(66) = -5.324$, $p > .001$. Overall, for all three same/different events involving the presentation of faces, exposure to words prior to faces slowed down the reaction time compared to prior exposure to faces and objects.

Objects task:

A one-way within subjects ANOVA was conducted to compare the effect of habituation on reaction time in perceiving objects. There was a significant effect on reaction time for perceiving objects, $F(2, 64) = 6.21$, $p < .005$. Again, three paired samples t-tests were used to make post hoc comparisons between conditions. There was no significant difference in reaction time between the objects following faces condition

(*M* = 1081.35, *SD* =396.97) and the objects following objects condition (*M* = 1072.58, *SD* = 393.36); *t*(66) = .482, $p > .5$. There was a significant difference in reaction time between the objects following faces condition (*M* = 1081.35, *SD* = 396.97) and the objects following words condition (*M* = 1184.19, *SD* = 476.37); *t*(65) = -3.55, $p = .001$. There was a significant difference in reaction time to objects following objects condition (*M* = 1078.81, *SD* = 393.03) and the objects following words condition (*M* = 1184.19, *SD* = 476.37), *t*(65) = -3.10, $p < .005$. Overall, for the same/different events involving objects, exposure to words prior to the objects slowed down reaction time compared to prior exposure to faces and objects.

Words task:

A one-way within subjects ANOVA was conducted to compare the effect of habituation on reaction time in perceiving words. There was a significant effect on reaction time for perceiving words, $F(2, 65) = 10.07$, $p < .001$. There was a significant difference in reaction time between the words following faces condition (*M* = 1228.08, *SD* = 443.70) and words following objects condition (*M* = 1370.53, *SD* = 550.81); *t*(66) = -4.36, $p < .001$. There was no significant difference in reaction time between the words following faces condition (*M* = 1228.08, *SD* = 443.70) and words following words condition (*M* = 1223.72, *SD* = 446.84); *t*(66) = .29, $p < .50$. There was a significant difference in reaction time between words following objects condition (*M* = 1370.53, *SD* = 550.81) and words following words condition (*M* = 1223.72, *SD* = 446.83), *t*(66) = 3.66, $p = .001$. Overall, for the same/different events involving words, prior exposure to objects slowed down reaction time compared to prior exposure to faces and words.

Standardized Test Results

A Pearson product-moment correlation coefficient was computed to assess the relationship between the four standardized tests- CFMT, TOWRE (subtest I and II), RAN and DANVA. There was a negative correlation between performance on the CFMT and RAN, $r = -0.299$, $n = 67$, $p = .014$, such that faster letter naming speed predicted better face memory. There was a positive correlation between performance on the CFMT and TOWRE, $r = 0.35$, $n = 67$, $p = .004$, such that word naming ability predicted face memory. Both subsets of the TOWRE predicted face memory, such that there was a positive correlation between performance on the CFMT and Sight Word Efficiency (subtest I), $r = 0.262$, n = 67, $p < .05$, and a positive correlation between the CFMT and Phonemic Decoding Efficiency (subtest II), $r = 0.392$, $n = 67$, $p = .001$. There was also a negative correlation between performance on the TOWRE and RAN, $r = -0.435$, $n = 67$, $p < .001$, such that faster responses to naming letters predicted better performance on words naming. Both subtests of the TOWRE predicted participant response time of naming letters, such that there was a negative correlation between performance on the RAN and Sight Word Efficiency (subtest I), $r = -0.466$, $n = 67$, $p < .001$, and a negative correlation between the RAN and Phonemic Decoding Efficiency (subtest II), $r = -0.361$, $n = 67$, $p < .005$. The DANVA was not related to the CFMT, but was marginally significant with the RAN, $r = .199$, $n = 66$, $p = .11$, such that faster responses to naming letters may predict nonverbal behaviors, and the TOWRE, $r = 0.207$, $n = 66$, $p < .1$, such that word naming ability may predict nonverbal behaviors.

Discussion

We were unable to address our hypotheses for the experimental task in this study, given that there was no evidence that our task resulted in habituation. Initially we had predicted that whenever words followed faces, and faces followed words, participant's reaction time would slow down due to habituation. This finding would have suggested behavioral evidence of similar neural underpinnings for the processing of faces and processing of words. Unfortunately, no habituation occurred and thus our hypothesis cannot be proven.

In other words, being exposed to words, faces, and objects did not slow responses to a subsequent task involving words, faces, and objects, respectively, which would be the case if habituation effects did occur. If words and faces slowed responses to the other as well, this would have supported behavioral evidence that there are similar neural underpinnings underlying these abilities. However, due to the lack of habituation we could not examine this predicted effect. Instead, we found that exposure to words slowed down participant's responses to faces and objects, whereas exposure to objects slowed down responses to words. Given that there was no evidence of habituation, it is unclear what caused these effects, but what is clear is that this paradigm was unable to address the current thesis.

Our findings, however, that the CFMT, TOWRE, and RAN correlate with one another is consistent with shared neural underpinnings of these abilities, and provides insight for future studies. Based on these findings we can conclude that face memory correlates with word processing abilities consistent with prior evidence for shared neural architecture underlying both processes. This correlation further increases our continued interest on the effects of neural habituation on face processing and word processing.

In terms of why our habituation task did not work, studies have shown that habituation increases with more intense, salient items (Thompson and Spencer, 1966). Also, habituation occurs faster the longer that one is exposed to it (Sincero, 2011). Thus, we could replicate the nine-block experimental task in the present study, but alter the stimuli to be presented in bright, bold colors rather than black and white, and displayed for a longer duration than 30-seconds. These changes would perhaps result in greater habituation. We would also want to examine the DANVA again since our results showed no correlation between the DANVA and the CFMT, which is inconsistent with past studies (Franklin & Adams, 2010; Palermo et al., 2013).

Since our results suggest that similar neural architecture is activated in detecting face memory and reading deficiencies (dyslexia), it would be interesting to further investigate this finding. We could examine if neural habituation to words or faces impairs face processing speed and word processing speed by utilizing a new manipulation task. We could have participants read a short story for approximately 30 minutes, and then have them perform a facial perception task, such as the DANVA. To study facial habituation on word processing speed, participants could be given a set of faces and told to memorize the faces for a period of time. We predict that studying portraits for an extended period of time would successfully lead to habituation among individuals. Following the face memory task, participants could read a short story and see if their timing slows down. However, we would then have to account for confounding factors such as fatigue.

Overall, although the manipulation in the nine-blocks of the experimental task was unsuccessful, we now have more insight into the neural architecture activated during face processing and word processing. Our findings on the correlations between the CFMT, RAN, and TOWRE show that similar neurons activate face memory and reading deficits. This finding provides much insight for future research on prosopagnosia and dyslexia. Continued exploration into the relationship between reading words and reading faces will result in a valuable understanding of the similar neurons activated during these processes.

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