PROPORTION MANIPULATIONS OF THE EMOTIONAL STROOP

PROPORTION MANIPULATIONS OF THE EMOTIONAL STROOP DIFFER FROM ATTENTIONAL MODULATION EFFECTS FOUND IN PROPORTION CONGRUENCY

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TITLE: Proportion manipulations of the Emotional Stroop differ from attentional modulation effects found in proportion congruency

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Lay Abstract

In three experiments, we investigated the role of proportionally more or less emotional interference on a colour naming task. Emotional interference in the form of emotional words was compared to response interference where participants see mismatched and matched colour words (e.g. the word 'NIGHTMARE' in green versus the word 'BLUE' in green). We expected participants to be able to learn which blocks contained more emotional word content and to adapt in order to reduce this slow-down effect. Instead, participants were especially slow on emotional words when they were in blocks that contained more emotional word interference. The possible importance of emotional stimuli to participants over the task demands of naming the colour of a word, as compared to other kinds of interference, is discussed.

Abstract

The Stroop effect is commonly demonstrated by measuring the time required to identify the colour of the ink (e.g. blue) in which a colour word (e.g. RED) is printed and illustrates a strong interference effect when the prepotent response of processing the word must be inhibited to respond correctly to the colour of the ink. Longer response latencies in colour-identification tasks involving emotional words versus neutral words, an effect dubbed the Emotional Stroop (ES), is often likened to the type of interference found in the Stroop task. However, research has suggested that the effect of attentional modulation in Stroop tasks may be very different from the kind of emotional interference found when comparing reaction times to emotional versus neutral words (McKenna & Sharma, 2004). Proportional congruency experiments using the Stroop task manipulate the *amount* of incongruity present in a block of trials (Logan & Zbrodoff, 1979), and demonstrate attentional modulation as a change in the size of the Stroop effect such that a greater amount of Stroop interference in a block is associated with a smaller Stroop effect. Manipulating the proportion of interference trials may inform understanding of the differences between Stroop colour-word interference and emotional-word interference. In three experiments, we manipulated the proportion of emotional words in a mixed-list design to study the effect of proportion manipulation on the ES. An enlarged ES was found in blocks of trials that contained more emotional interference; a finding contrary to attentional modulation seen for proportion manipulations of congruency in the Stroop task. The differences between the ES effect and the Stroop effect are discussed, including the role of response incongruity as one possible reason for the discrepancy.

Acknowledgements

I am forever grateful for the mentorship, friendship, and support I have received from my supervisor, Judith Shedden. Many advisors would have given me up as lost after family demands pulled my life in a different direction and led to a resulting prolonged absence from the department. Judy did not. Instead, she offered me nothing but love, support, and encouragement as we worked together to produce the research paper that would become my master's thesis. It was not the PhD thesis we had both once planned, but then, life does not always happen in a straight line; there are twists and turns, bends and curves to even the most well-travelled road. It was Judy who resumed contact with me to ask after the research projects I had left unfinished in the lab. I had been certain that our first meeting would be filled with disappointment on her end. I will never forget that Judy offered me her hand and not her shoulder on that fateful day.

I am happy to have been able to complete a research project that I can feel proud of and that can act as a testimony to the work and learning I achieved within the department of Psychology, Neuroscience & Behaviour. The fierce passion for science within the department was ever an inspiration and I will treasure my memories of colloquium wine and cheese filled with opportunities to engage top researchers on their topics of expertise, and for the reading groups where an awful lot of deep thinking and great conversation happened.

After the pandemic left me literally riddled with children and a masters to finish in t-minus 2 months, my wonderful parents-in-law stepped in to give me the time I needed to make this whole thesis possible. Whatever you need they told me. Thank you to Mark Altman and Pnina Altman, my wonderful, beautiful child-caring angels.

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Thank you to my children for letting me work 'some of the time.' To Brennan, thank you for being my jailor and checking off the tasks I had completed before we could play. Thank you for telling me I may need to test people using that 'colour word thingy' at my defense. I guess I…could? Thank you to Kieran for all the lost playtime and thank you to my little princess Thea who has had no idea what's been going on but who might someday feel a little bit proud that her mummy did a thing. Hopefully she'll be all the more proud knowing it was completed inbetween changing poops and giving her 'brrm brrms.'

Finally, no acknowledgements section would be complete without mention of the wonderful people who were my friends, colleagues, and academic siblings in the Shedden lab. There are so many people who helped shape me into the researcher I am today; Jennifer Heisz, Jim Karle, Evan Harvey and a slew of wonderful undergraduate students who believed in my work and without whom I would have been lost. A special shoutout to Soumya Saini, Heli Tank and Amy Pellarin whose efforts with participant collection was crucial when conducting studies measuring small, subjective emotional effects.

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Declaration of Academic Achievement

My thesis project investigated the relationship between emotion, cognitive control, and applying cognitive control in situations involving more or less emotional interference. To this end, I conducted three experiments where the level of emotional interference was manipulated on a block-wide scale.

Introduction

An individual's entire history and past experience with a word determines its importance and whether it has emotional value to them; a person who was bitten by a dog as a child will have a very different reaction to the word 'dog' than someone who once had one as a family pet. Slower responses to triggering words for unrelated tasks were first noticed in clinical patients who were sensitive to words associated with their pathologies (for a review see: Williams, Matthews, & MacLeod, 1996). These patients were slower to name the ink-colour of a word if the word was related to their condition (e.g., the word "eating" for a patient suffering from eating disorders). Soon after, the research world learned that the effect could be found in other groups so long as the words used in the experiment were important to those individuals. For instance, spider-phobic participants are slower to name the colour of spider words (Watts et al., 1986) while math anxious participants are slower to name the colour of math words (Suarez-Pelliconi & Nunez-Pena, 2015). This emotional interference was labelled the Emotional Stroop (ES; Williams, Matthews, & MacLeod, 1996).

The negative nature of important words is important in eliciting an ES and studies have found a lack of the same slowdown when naming positive emotional words (Pratto & John, 1991). There is something special, it seems, about words that are both important to us and that carry a negative label. What constitutes a negatively labelled word/concept is so variable among individuals that it is sometimes not found for general negative emotional stimuli in nonclinical groups (Phaf & Kan, 2007, Peach et al., 2012) although those higher in anxiety are more likely to show an ES in a nonclinical group (Eggloff & Hock, 2001).

In contrast, the classic Stroop effect, for which the ES effect was named, involves the use of congruent and incongruent colour words and is considered a general robust measure of cognitive control that is readily found in the general population (for a review see: MacLeod, 1991). Relying on response incongruity, rather than emotional interference, the classic Stroop effect presents colour words in a matching or mismatching colour to create congruent and incongruent stimuli (e.g., the word BLUE presented in RED would be considered an incongruent trial while the word BLUE presented in blue would be a congruent trial). Like the ES, participants must overcome the interference being presented to them at the word reading level on incongruent trials while they receive a facilitation effect from the word during congruent trials (e.g., the colour of the word BLUE presented in blue is identified faster than the colour of the word RED presented in blue). The Stroop effect is encapsulated by shorter reaction times to congruent (facilitatory words) as compared to incongruent (interference) words.

Both the Stroop and ES effects involve overcoming interference presented to them at the word reading level in order to complete the colour naming task; this similarity in theoretical underpinning is what led to the term Emotional 'Stroop'. However, unlike the classic Stroop effect, the word interference that participants in an ES study must overcome lacks the response congruence to assist or conflict with the task at hand. Instead, it is purely an effect of the emotional reaction a participant has to a particular word.

Further support for differences between the two Stroop effects comes from a study conducted by McKenna and Sharma (2004) where a ‘slow’ component was revealed for the ES by using short inter-trial intervals. By shortening the inter-trial-interval, the ES was found to have a large carryover effect onto the subsequent trial that may be the driving force of this effect. This is in contrast to an interpretation of the ES as having a direct emotional impact on the emotional word trial itself, although impacts on the trial itself have also been found (Frings et al., 2010).

The presence of a large ‘slow’ component to the ES could help to explain why studies in which emotional words are equally mixed with neutral words (mixed-lists) don’t always show an ES effect (Holle, Neely, Heimberg, 1997; Richards et al., 1992). Instead, emotional words are often compared to neutral words across blocks. A meta-analysis by Phaf and Kan (2007) reviewed over 70 studies of the ES and determined that it had the largest effect size in clinical populations where words were blocked and its weakest effect size in nonclinical groups where emotional words and neutral words were mixed within a block (mixed-list design). Block-wide presentation may benefit from the slow component which would be impacting only emotional words and reinforcing the difference between the two words. This is in contrast to the classic Stroop which is a robust phenomenon that is highly recognizable in mixed-list designs (MacLeod, 1991).

Studies of the classic colour-word Stroop effect have noted attentional modulation that varies with the proportion of incongruent trials in a block. This modulation allows participants to manage proportion manipulations of congruency in a way that optimizes their performance on the task. Known as the Proportion Congruency (PC) effect, varying the proportion of congruency in a block amounts to smaller Stroop effects in blocks where more incongruent (mismatched) trials are presented compared to blocks where more congruent (matched) words are present (Logan, & Zbrodoff, 1979). Reaction times in blocks where more incongruity is present show a reduced Stroop effect that is taken to mean participants are behaving more cautiously to all stimuli while blocks with more congruency show a larger Stroop effect that is taken to mean more participant reliance on the (mostly) beneficial word reading strategy (attention is relaxed to allow for the benefit of word reading).

This attentional modulation is sensitive to context (Crump & Milliken, 2006), so that PC effects can be restricted to contextual features such as certain locations, or even certain sets of items (Item Specific Proportion Congruent: Jacoby, Lindsay, & Hessels, 2003) that possess proportion manipulations (the words blue and yellow are more likely to be congruent while red and green are more likely to be incongruent).

Interpretations of the process behind Stroop interference and ES interference focus on attention being directed to the word reading process versus the colour naming process. Word reading is such a strongly automated response that the presence of a word versus a string of letters still provides interference on the colour naming task; people can't help but read the word (Brown et al., 2002, Augustinova & Ferrand, 2014). When that word impacts performance, whether by containing emotional interference or response congruity, additional attention is recruited to support task performance. It is the responsiveness of the attentional system to interference or facilitation within the experiment context that is believed to be at the heart of PC attentional modulation effects (greater incongruent trials cause participants to focus more on colour naming). Although the ES lacks the facilitation effect that comes from congruency, participants must still overcome interference at the word reading level in order to perform optimally. It follows, then, that presenting a similar number of interference trials for ES stimuli should produce attentional modulation that mimics that of PC effects; attention should be directed away from the word and towards the colour when more interference is present during blocks with more emotional words.

A study by Krug and Carter (2012) incorporated emotion into a PC design by presenting congruent and incongruent expressive face-word pairings. They found an attenuation of attention similar to classic PC effects in an experiment that used emotional stimuli as part of the Stroop design. In this study, participants were presented with a face stimulus that contained a word overlay that could be congruent with the face (a fear word overlaid on a fear face) or not (a fear word overlaid on a neutral face). The task was to indicate whether the face stimulus was neutral or fearful. Participants in this study experienced an emotional mismatch on incongruent trials, leading them to have longer reaction times to faces that were shown with an emotional mismatch. This study suggests that the introduction of emotion into a Stroop design still produces PC effects although, the incongruent picture stimuli used in this experiment contained response incongruity unlike the emotional words used to generate the ES effect. This experiment demonstrates that studies incorporating emotion into a PC design with congruence produces the same type of attentional modulation as PC experiments with the classic Stroop.

In an effort to better understand the differences between the ES and the Stroop, we present three experiments using mixed-list proportional manipulations of the ES in a group of non-clinical participants. As habituation due to repeated word presentation has been implicated in the lack of an ES within mixed-list designs (Ben-Haim, Mama, & Algom, 2014) we made a decision to present novel emotional content wherever possible. Our goal in examining proportion manipulation effects on the ES was to make the emotional interference in a block of trials as similar as possible to congruency interference which presents a problem where response incongruity is ever present in the Stroop effect while emotional reactivity dissipates on repeated word presentation. Using novel emotional words on every trial allowed us to preserve the level of emotional interference throughout a block in order to better simulate the conditions known to produce PC effects (response congruence).

Another method we employed to examine proportion manipulations of the ES was to select a subset of participants who demonstrated an overall ES to our particular word set. As our goal was not to see whether we could demonstrate the ES for our particular group of subjects with our list of generalized emotional words, we employed a selection method of creating ES subset groups to assess list-wide proportional modulation of the ES. Based on average reaction time differences for emotional versus neutral words, we analyzed a group of participants who were sensitive to the emotional words in the study. This method eliminated the difficulty in tailoring our word lists to specific participants and allowed us to assess variation in the ES across block-wide proportion manipulations.

Experiment 1

Introduction

In order to test the possibility that the ES will trigger a similar block wide attentional modulation as has been seen in PC effects, we manipulated the ratio of emotional to neutral words within a block of trials. Participants completed a block high in emotional content (80%), a block low in emotional content (20%) and a block where emotional content mimicked that used in mixed-list designs (50% emotional). If it is true that emotional interference requires the same application of control in order to overcome the word level interference, then it should be possible to manipulate the ES effect in a similar way as that seen with the Stroop; the ES effect should be smaller in blocks with more emotional interference, and larger in blocks with less emotional interference.

Method

Participants

First year undergraduate participants from McMaster University participated in this experiment for course credit. A total of 57 (16 male) participants took part in this study. The procedures in this experiment were approved by the McMaster Research Ethics Board (MREB) and complied with the Canadian tri-council policy on ethics.

Materials and Apparatus

All stimuli were presented using Neurobehavioural Systems' Presentation software (version 14.5) on a Pentium 4 computer running Windows XP (Professional Edition). The stimuli were presented on a 17" CRT monitor, at a resolution of 1024x768. The refresh rate on the monitor was set to 85 Hz. Participants completed the experiment individually in a dimly lit room. All stimuli were presented on a black background.

Stimuli

Words selected for the ES task were drawn from the Affective Norms for English Words (ANEW) as developed and tested with undergraduate students by Bradley and Lang (1999). Words from the ANEW are rated on a variety of measures including valence. The valence of each word in the ANEW has been rated on a scale ranging from 1 - 9, with 1 indicating a strongly negatively valenced word and 9 indicating a strongly positively valenced word. The criteria used to select emotional words for this study were a valence score less than 2.5 for negative emotional words and a valence score within the range of 4.25 and 4.75 for neutral valenced words. An analysis of the word scores revealed that the words differed on valence, $t(137)= 61.927$, $p < .001$, and arousal, $t(137)= -8.31$, $p < .001$, but not word frequency, $t(137)= .384$, $p = .702$. In all, 138 words were selected from each category (total 276 words) for use in this study with an additional 20 neutral words selected for use in the practice block.

Procedure

After obtaining informed consent, participants were led to a dimly lit room where they completed the experimental task.

Participants were asked to report the colour of the word on the screen and to indicate their response with a key press. Words could appear in one of four colours (green, red, blue, yellow), each of which was associated with a response key ('z', 'x', '.', '/'). The experiment began with a short practice block of 20 trials during which only neutral words were presented.

Following the practice block, participants completed three experimental blocks. The order of block presentation was randomized. Blocks contained 92 trials and were composed of varying proportions of emotional and neutral words. The emotional high block contained 80% emotional words, the emotional low block contained 20% emotional words and the equal block contained 50% emotional words. The order of words within a block was randomized and words subtended a visual angle of 1.131° X 1.508° - 6.777° (depending on word length). Participants saw a novel word on each trial presentation.

Prior to each word, a fixation cross, font size 40 in Times New Roman, was centrally presented for 750ms. The coloured word stimuli then appeared for 500ms after which the screen became blank until the participant made a response. Every 23 trials participants encountered a break screen. The break screen contained a report of participant accuracy on the previous 23 trials as well as a reminder of which response key was associated with which colour.

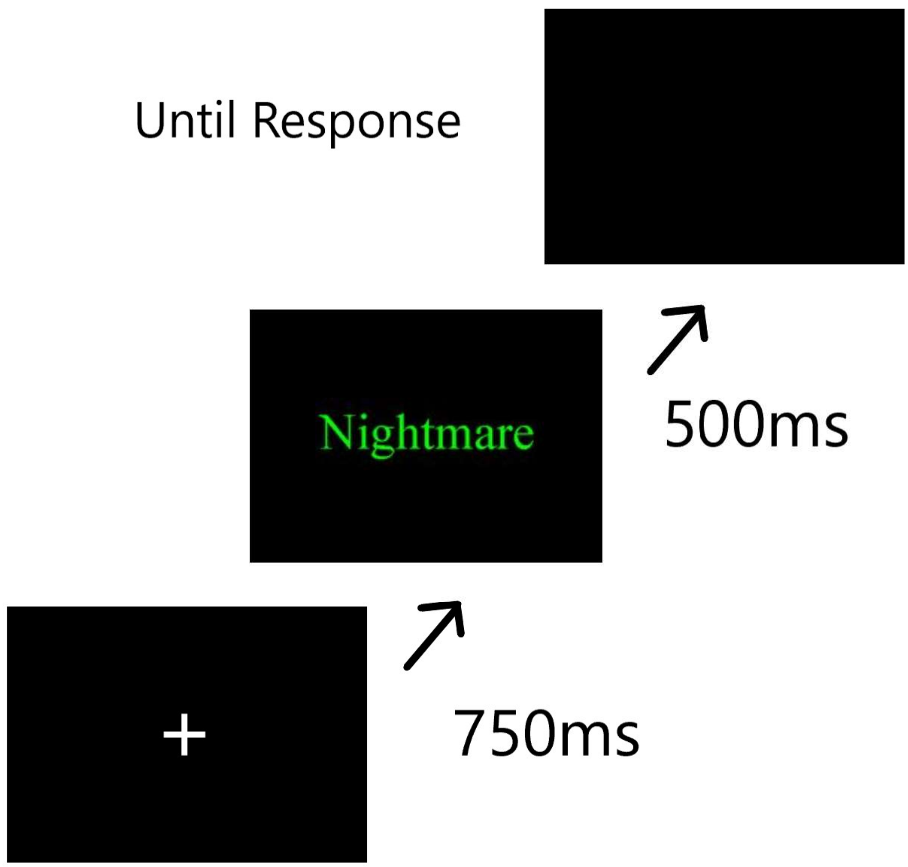

Figure 1.

An example of the trial structure used throughout these experiments. Here, an emotional word appears as the word stimuli. Participants are tasked with naming the colour of the word.

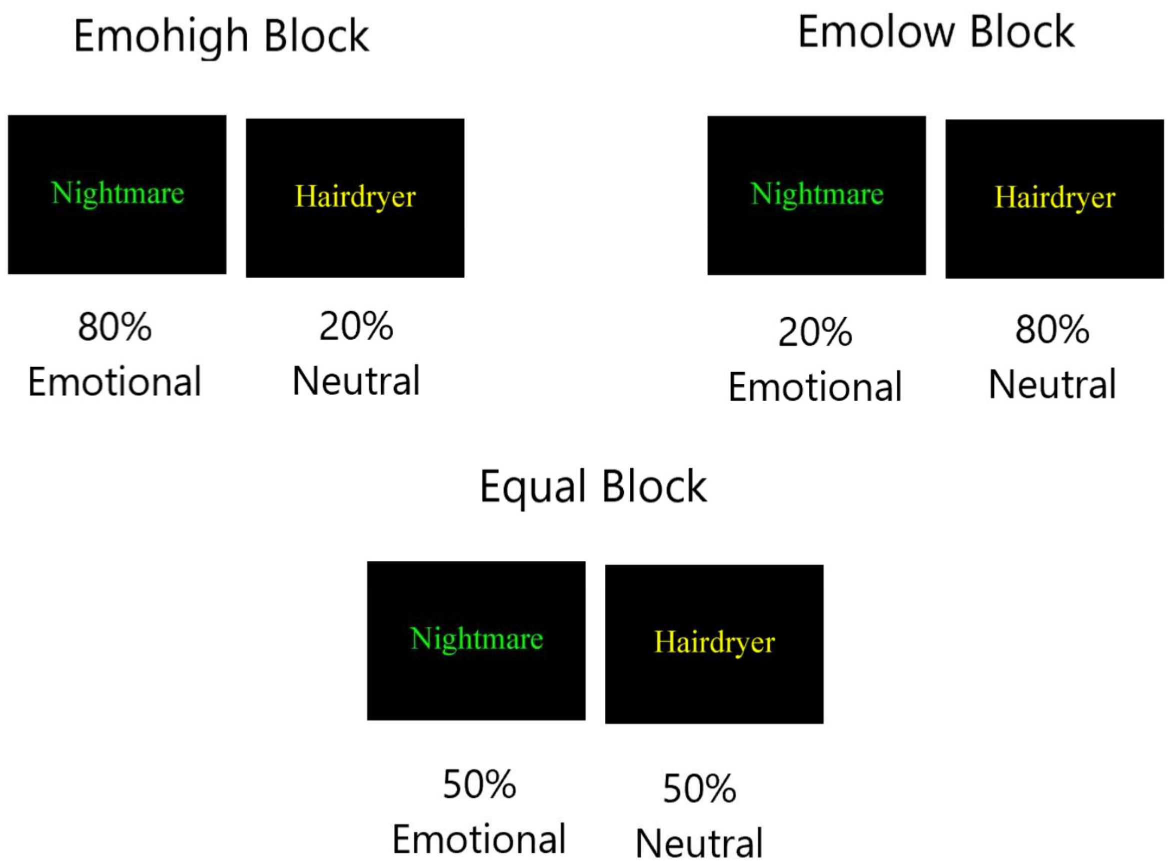

Figure 2.

Participants saw three block types in Experiment 1: high and low emotional content blocks that presented a strong proportion manipulation (80% or 20% neutral respectively) and an equal block designed to mimic mixed list designs of the emotional Stroop (50% emotional).

Results

All Subjects

Reaction time and Accuracy

An accuracy criterion was set at 70% which led to the exclusion of 1 participant. A total of 56 participants were included in the following analyses. A 3 (block type: emohigh, emolow, equal) by 2 (stimulus type: emotional or neutral) repeated measures ANOVA was performed on data from the remaining subjects (n=56). Unsurprisingly for a nonclinical sample, no main effects and no interactions were found within the reaction time data (See Figure 3) or the proportion of correct responses (See Figure 4).

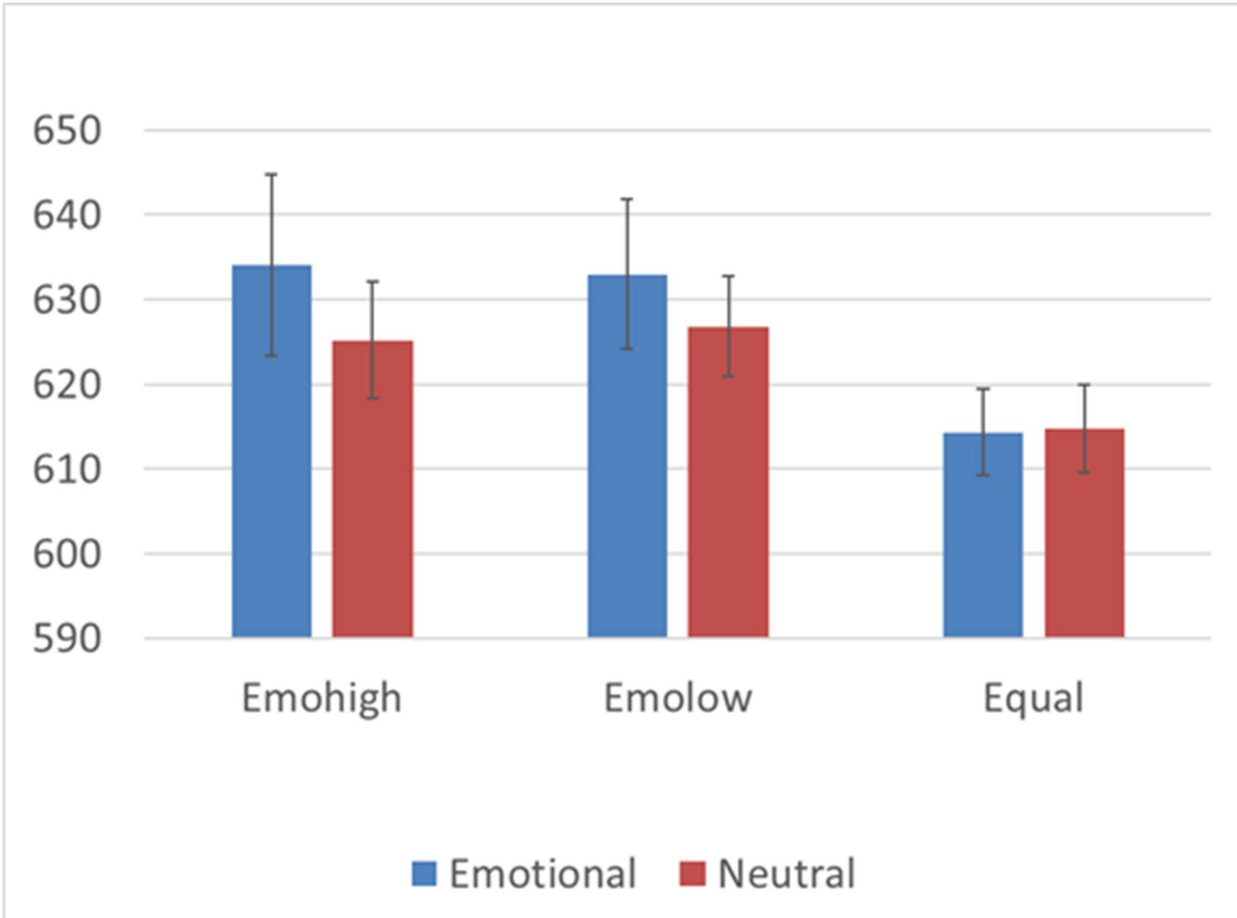

Figure 3.

Experiment 1 reaction time data when all subjects were included in the analysis. No main effects or interactions were found.

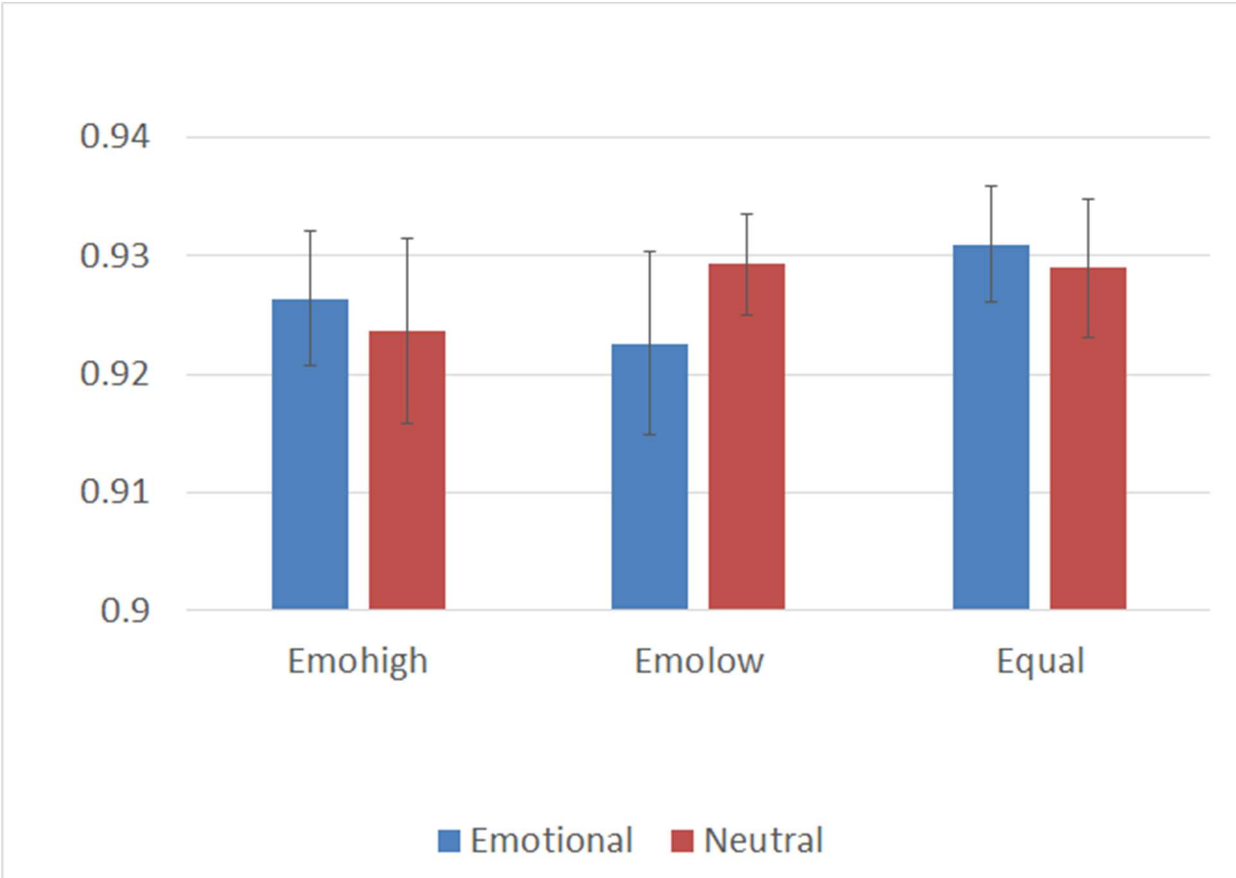

Figure 4.

The proportion of correct responses to emotional and neutral words from Experiment 1. All subjects are included in this graph.

ES Subset

Our intention was to gain an understanding of how proportion manipulations of the ES affected the size of the effect. As a result, our next analysis was restricted to a subset of participants who demonstrated the ES. This method of selection allows us to look at variations of the ES without being concerned about the general emotional impact of our particular word set. In order to better examine how the ES varies across block type in a non-clinical population, a subset of participants who demonstrated greater reaction time to emotional words across the experiment (greater than 0 ms) were selected (n= 25).

Reaction Time

A 3 (block type: emohigh, emolow, or equal) by 2 (stimulus type: emotional or neutral) repeated measures ANOVA was conducted on the ES group of participants. A main effect of stimulus, wherein participants were slower to respond to emotional words, demonstrated that our subset of participants did demonstrate a sensitivity to emotional words, $F(1, 24) = 7.894$, $p = .01$. An effect of block type was found, $F(1,24) = 5.96$, $p = .005$. Follow-up paired t-tests revealed that this main effect represented longer response times for stimuli within the emohigh block type relative to the emolow block type, $t(24)= 3.428$, $p = .002$, and the equal block type, $t(24) = 2.667$, $p = .013$. Both t-test comparisons were significant when alpha was corrected for multiple comparisons ($p = .016$) The emolow and equal block types did not differ from one another, $t(24) = -.609$, $p = .58$. A trend for a block type by stimulus type interaction was found, $F(1, 48) = 2.732$, $p = .075$. Given our a priori hypothesis that the ES would differ based on block type, we felt secure in pursuing this interaction to better examine how the ES varied as a function of block type. Follow-up t-tests revealed that the ES was present in the emohigh block type, $t(24) = 2.812$, $p = .01$, but not the emolow block type, $t(24) = 1.003$, $p = .326$, or the equal block type, $t(24) = .844$, $p = .407$ (See Figure 5).

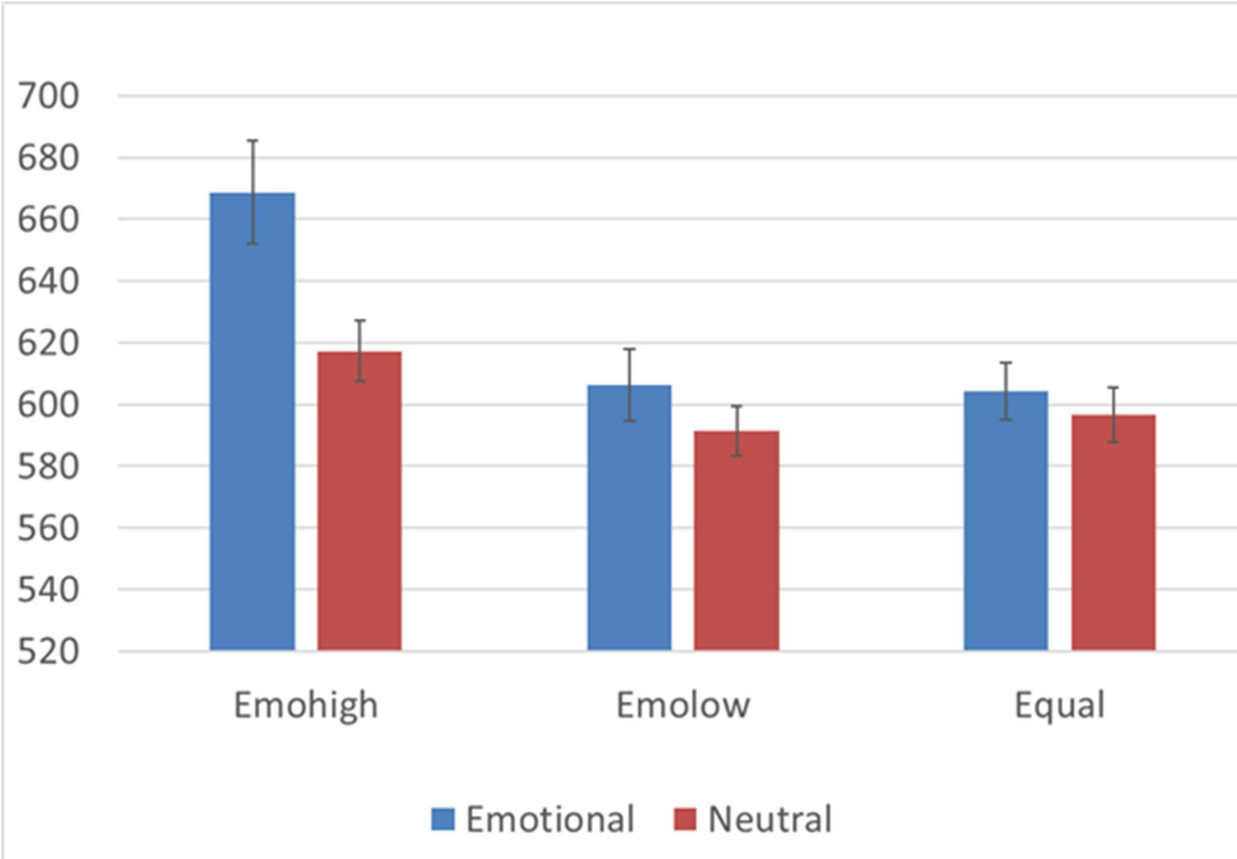

Figure 5.

Reaction time to emotional and neutral words for the subset of participants in Experiment 1 who demonstrated longer response latencies to emotional words. An ES was found in the emohigh block but not in the emolow or equal block.

Accuracy

The same analysis was conducted on the proportion of correct responses within the ES group. No main effects or interactions were revealed (See Figure 6).

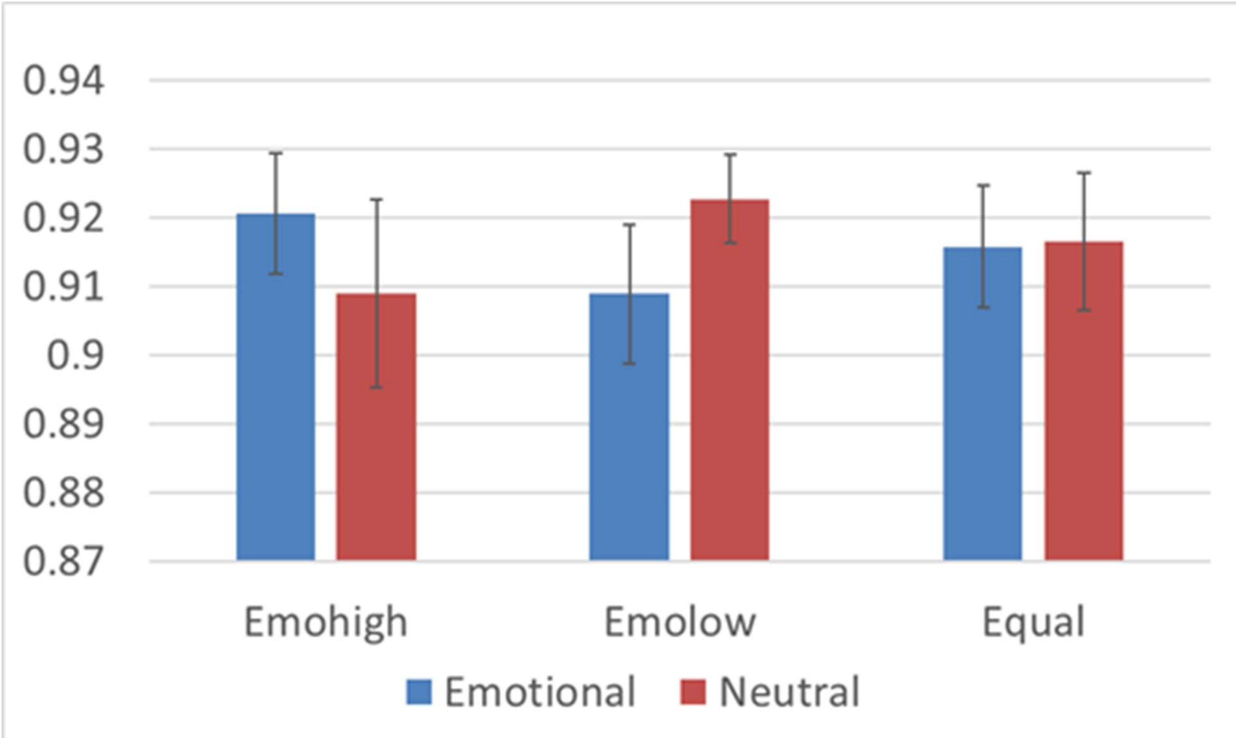

Figure 6.

The proportion of correct responses to emotional and neutral words for subjects in Experiment 1 who demonstrated longer response latencies to emotional words. There were no main effects or interactions.

Discussion

Experiment 1 demonstrated that the ES is sensitive to a proportion manipulation. However, the nature of this sensitivity was very different from that of proportion manipulations using the classic Stroop where blocks with more incongruence lead to a reduced Stroop effect. In contrast to proportion manipulations with the classic Stroop, Experiment 1 found an enlarged ES in the high proportion block which included the most interference in the form of emotional words.

This finding is more in line with the blocked approach taken when studying the ES where a difference between emotional and neutral words is more likely to be found when the word types are separated into distinct blocks. The mixed-list design block (equal emotional and neutral trials) replicated the finding that mixed-list designs do not show an ES effect (Phaf & Kan, 2007). The presentation of a block type with less emotional interference did not greatly impact participants when they encountered an emotional word, as evidenced by the lack of a Stroop effect in this block. This experiment would suggest that the ES does not allow for the introduction of a beneficial attentional modulation strategy to meet task demands.

One possible explanation for our findings in Experiment 1 relates to the order in which blocks are presented. Ben-Haim and colleagues (2014) found that participants experienced an increased negative mood over the course of an ES experiment, and critically after a block of emotional words. This effect was particularly large when novel word stimuli were used. A reduced mood in reaction to a large number of emotional words may mean that participants in Experiment 1 who saw more emotional words at the start of the experiment were induced into a negative mood that affected their responses to emotional words in later blocks; in the Ben-Haim study, neutral blocks that followed emotional blocks were considerably slower. With three block types and a subset of participants, it was impossible to assess the role of block order on the proportional manipulation of the ES in Experiment 1. Experiment 2 removes the equal block in order to examine block order as a potential key variable in the proportion manipulation effect we noted in Experiment 1.

Another interesting difference that could impact learning is the lack of S-R relatedness within studies of the ES compared to the Stroop. As a consequence of requiring S-R conflict to produce congruent and incongruent stimuli, proportion congruent experiments require the use of a limited set of stimuli (colour words and colour of the font) that are repeated across the block of trials. In contrast, the ES relies only on the emotional impact of the word presented allowing for novel stimuli to be presented on every trial. In order to examine the role of novelty further, Experiment 2 repeated the emohigh and emolow blocks with the same stimuli (e.g., the same words presented in the same font colour) as those shown in the first block presentation. This inclusion allowed us to explore the role of novelty (differences in attentional block-wide modulation across first versus second presentation) while also observing the impact of a practice effect with our general block types on the proportion manipulation effect found in Experiment 1.

Experiment 2

Introduction

Experiment 1 demonstrated that, like the Stroop effect, the ES effect is sensitive to block content proportion manipulations. Interestingly, our trial content proportion manipulation of the ES resulted in the opposite reaction to that of the classic Stroop. Rather than showing a reduced ES in a block high in emotional content, participants showed a larger ES in the high emotional content block and did not demonstrate an ES in the low emotional content or the equal emotional-neutral content block. The reasoning given for the classic proportion congruency effect, namely that participants become more controlled in the presence of more incongruency and more automatic in the presence of less incongruency, seems not to apply to the ES. However, it should be noted that Experiment 1 included an additional equal emotional content block (50/50 emotional/neutral words) that is typically not required to produce classic proportion congruency effects (for a review see: Bugg & Crump, 2012). In order to better compare a proportion manipulation of the ES to studies of proportion congruency, Experiment 2 removed the equal block from the design.

Experiment 2 also repeated the high emotional and low emotional blocks in order to assess the value of repeated exposure to the same words. As mentioned previously, PC effects with the classic Stroop typically use only a few words due to the limitations of S-R mappings. In Experiment 1, novelty was present on every trial. If novelty was an important factor in generating results at odds with PC effects for the classic Stroop, we should expect to see it diminished with repeated block presentations.

Methods

Participants

Undergraduate participants from McMaster University participated in this experiment for course credit. A total of 45 (8 male) participants took part in this study. The procedures in this experiment were approved by the McMaster Research Ethics Board (MREB) and complied with the Canadian tri-council policy on ethics.

Materials and Apparatus

The materials for Experiment 2 were identical to Experiment 1.

Procedure

The procedure for Experiment 2 was nearly identical to Experiment 1 with the exception that the equal block was removed and the emohigh and emolow blocks were repeated for a total of four experimental blocks. Participants alternated between emohigh and emolow blocks in a predetermined order. That order was then repeated in the second repetition for a total of four experimental blocks (emohigh-emolow-emohigh2-emolow2, emolow-emohigh-emolow2-emohigh2). Block order (emohigh-emolow, emolow-emohigh) varied by participants so that half of the participants saw the emotional high content block first and the other half saw the emotional low content block first. During repetition 2 (emohigh2, emolow2) participants saw the same stimuli they had seen in the first block set although the order of trial presentation was randomized (e.g. Nightmare in GREEN appearing in emolow for its first presentation would appear again in emolow2 but not in the same trial sequence). See Figure 7 for a review of the experimental procedure.

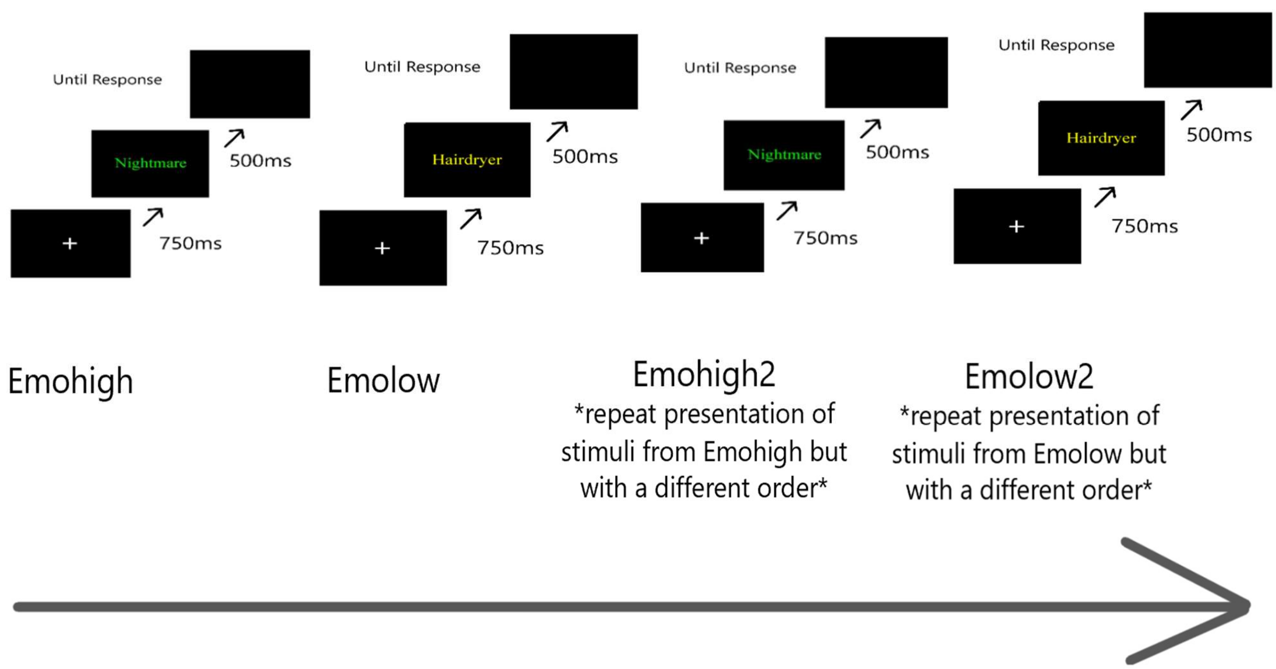

Figure 7.

A visualization of the procedure used in experiments 2 and 3. Note that half of the participants saw the emohigh block first (as depicted here) and the other half saw the emolow block first. Block order presentation was maintained in the second repetition and the stimuli presented were the same as in the first block, though the order of presentation was randomized.

Results

All Subjects

Reaction Time

The accuracy criterion was set at 70% which led to the exclusion of six participants from the analysis. Of the remaining 40 participants, an additional 4 were excluded in an arbitrary fashion (last four participants collected) in order to create equal block order groups for further analysis. A 2 (block type: emohigh, emolow) by 2 (stimulus type: emotional or neutral) by 2 (repetition: 1 or 2) by 2 (block order: emohigh-emolow, emolow-emohigh) ANOVA was performed on the remaining subjects (n=36). Similar to Experiment 1, no main effects and no interactions were found for the reaction time data (See Figure 8).

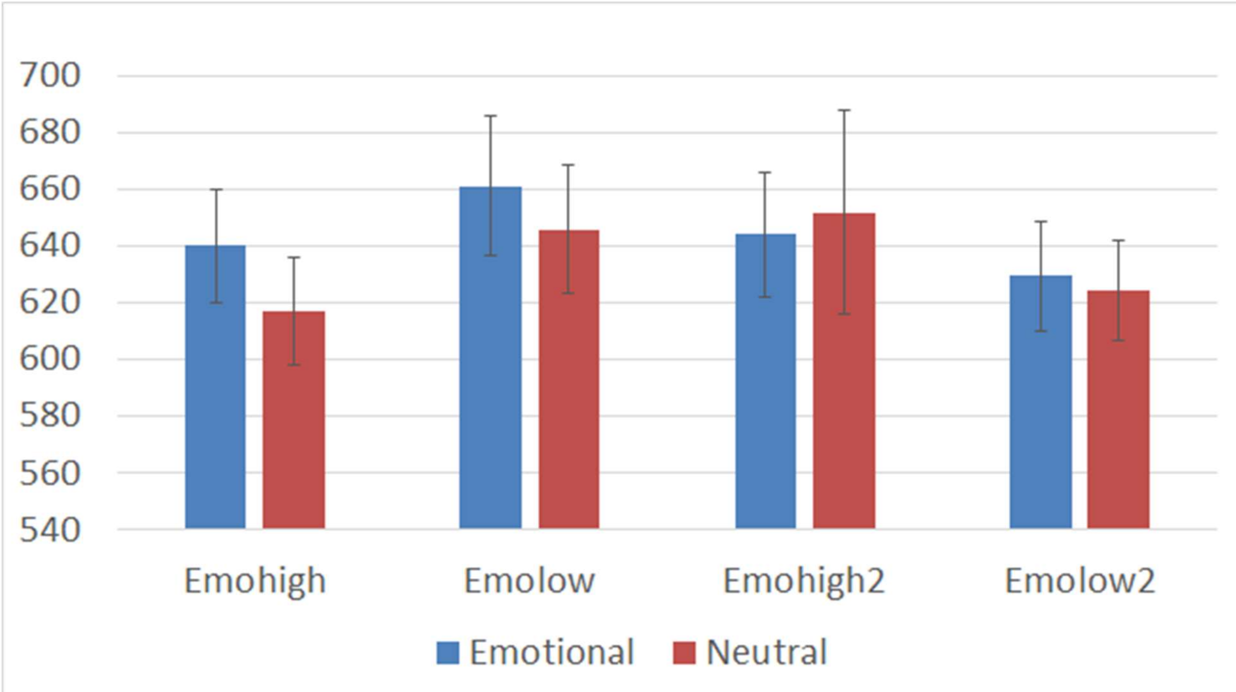

Figure 8.

Reaction time data for all subjects from Experiment 2. No main effects or interactions were revealed. Note that the error bars represent between subject variance.

Accuracy

The same analysis was conducted on the proportion of correct responses. This analysis revealed a repetition effect where participants were more accurate in the second repetition, $F(1, 34) = 6.173$, $p = .018$ (See Figure 9). An interaction between repetition and block order was found, $F(1, 34) = 7.358$, $p = .01$. Follow-up comparisons revealed that participants were more accurate in the second repetition when they had seen the block order emohigh-emolow, $t(17) = -2.872$, $p = .011$, but not when they had seen the block order of emolow-emohigh, $t(17) = .781$, $p = .446$ (See Figure 10 and 11 respectively).

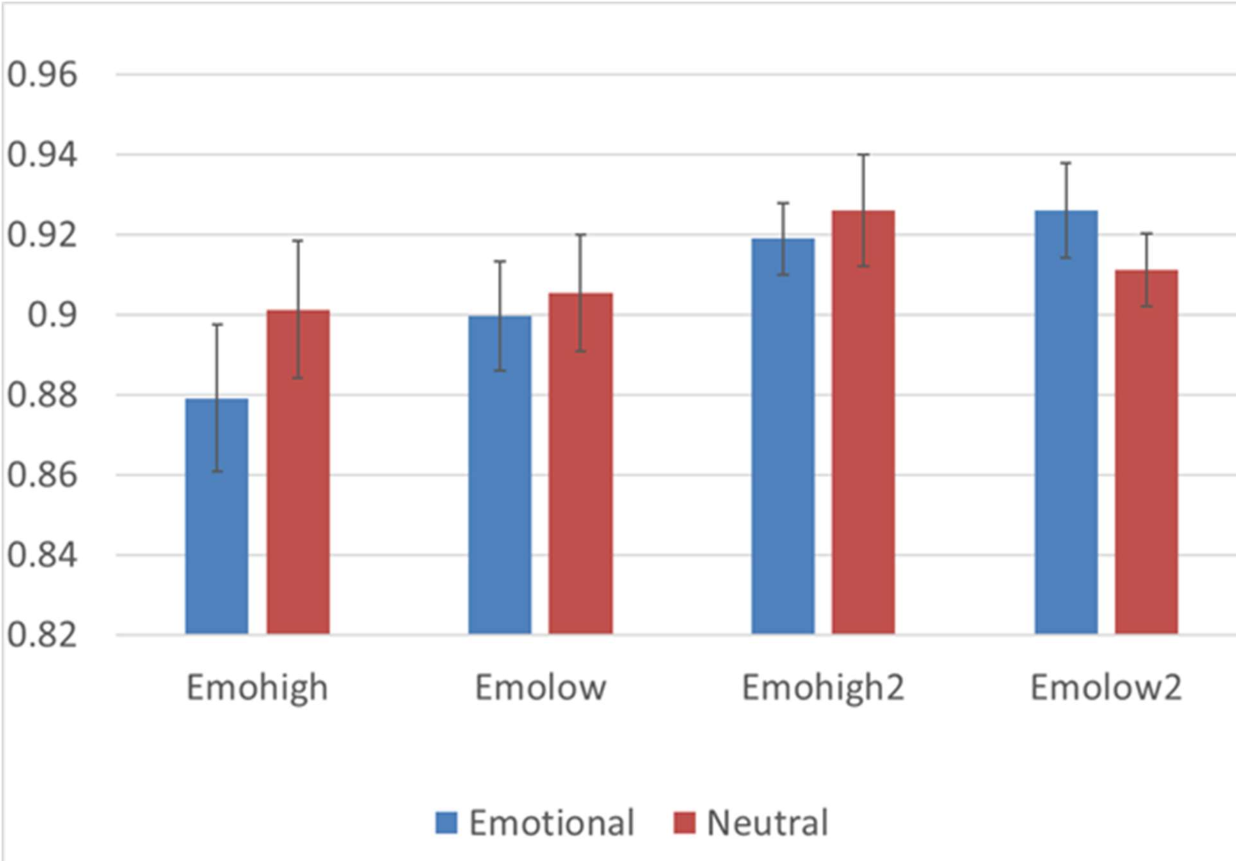

Figure 9.

The proportion of correct responses for all the subjects in Experiment 2. Participants were more accurate in the second block repetition. A repetition by block order interaction was also found. Note that the error bars represent between subject variance.

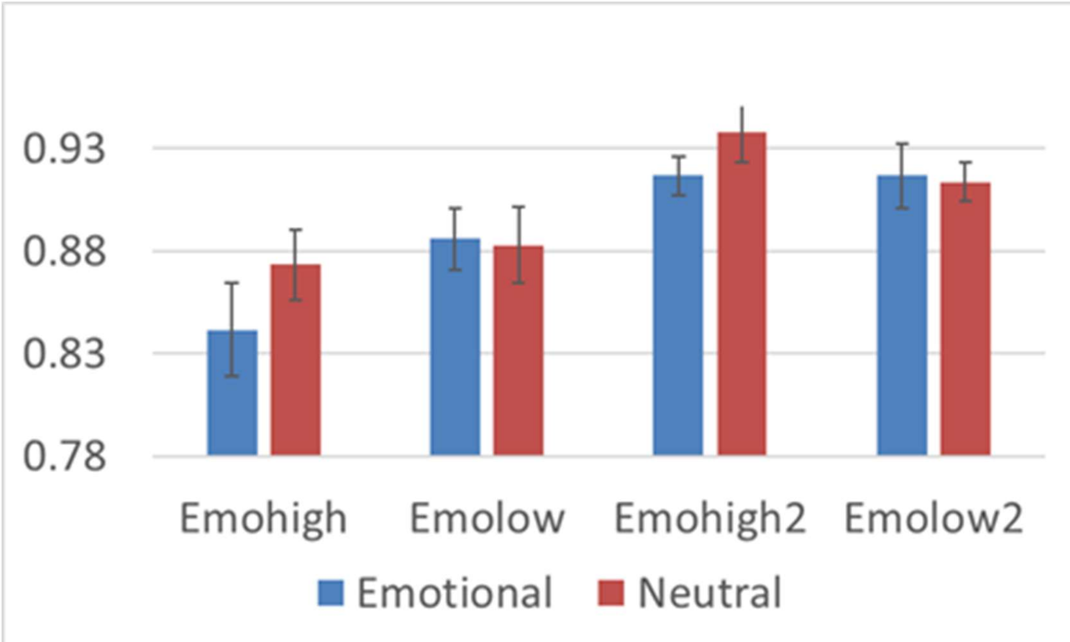

Figure 10.

The proportion of correct responses for participants who saw the emohigh-emolow block order in Experiment 2. A main effect of repetition was found.

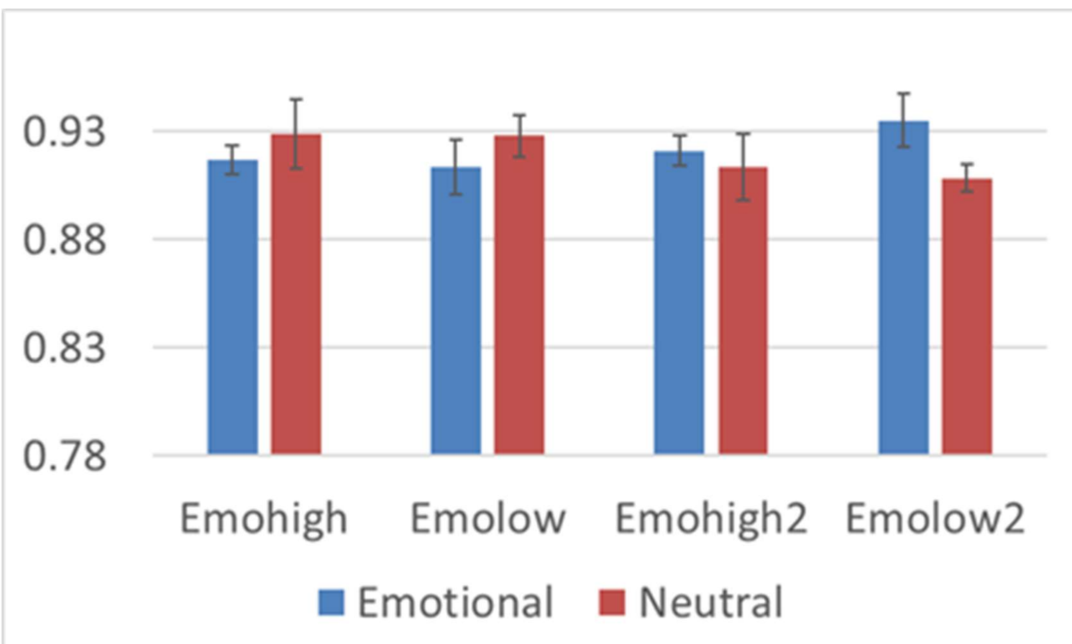

Figure 11.

The proportion of correct responses for participants who saw the emolow-emohigh block order in Experiment 2. No effect of repetition was found within this block order.

ES Subset

In an effort to be as inclusive of participants demonstrating the ES as possible, participants were included in the analysis if they showed an ES over the first block repetition, OR the second block repetition (n = 27). By grouping participants this way, only those participants who did not demonstrate the ES at all during the experiment were omitted from the following analyses.

Reaction Time

An additional three participants were excluded in an arbitrary fashion (the last 3 participants collected) in order to equalize the number of participants across block order groups. The remaining 24 subjects were included in the following analyses. A 2 (block type; emohigh, emolow) X 2 (Repetition: 1 or 2) X 2 (stimulus type: emotional or neutral) ANOVA with the between subjects factor of block order (emohigh first, emolow first) was performed on participant reaction time to the colour task. A main effect of stimulus type was found, indicating that our selection of participants who showed the ES was successful, $F(1,22) = 12.349$, $p = .002$. All other effects were null although a trend was noted for participants to be faster in the second repetition, $F(1,22) = 3.279$, $p = .084$.

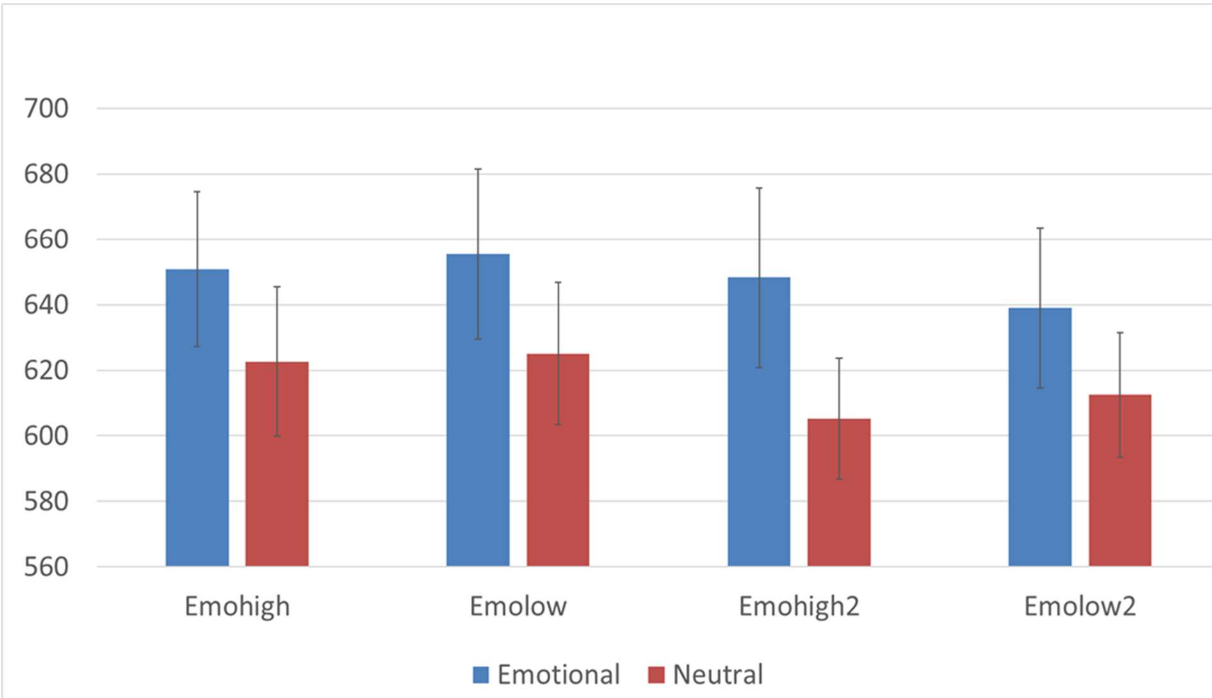

Figure 12.

Reaction time data for participants in the ES subset of Experiment 2. Participants were faster on neutral words relative to emotional words and there was a trend for them to be faster in the second block repetition. Note that the error bars represent between subject variance.

Accuracy

A 2 (block type; emohigh, emolow) X 2 (Repetition: 1 or 2) X 2 (stimulus type: emotional or neutral) ANOVA with the between subjects factor of block order (emohigh first, emolow first) was performed on participant proportion of correct responses for the colour task. An interaction between repetition and stimulus type was revealed, $F(1,22)= 6.358$, $p= .019$. Follow-up analyses indicated that this interaction was due to more accurate responding to emotional words in the second repetition, $t(23) = 2.107$, $p = .046$ but not the first, $t(23) = -.967$, $p = .344$ (See Figure 13).

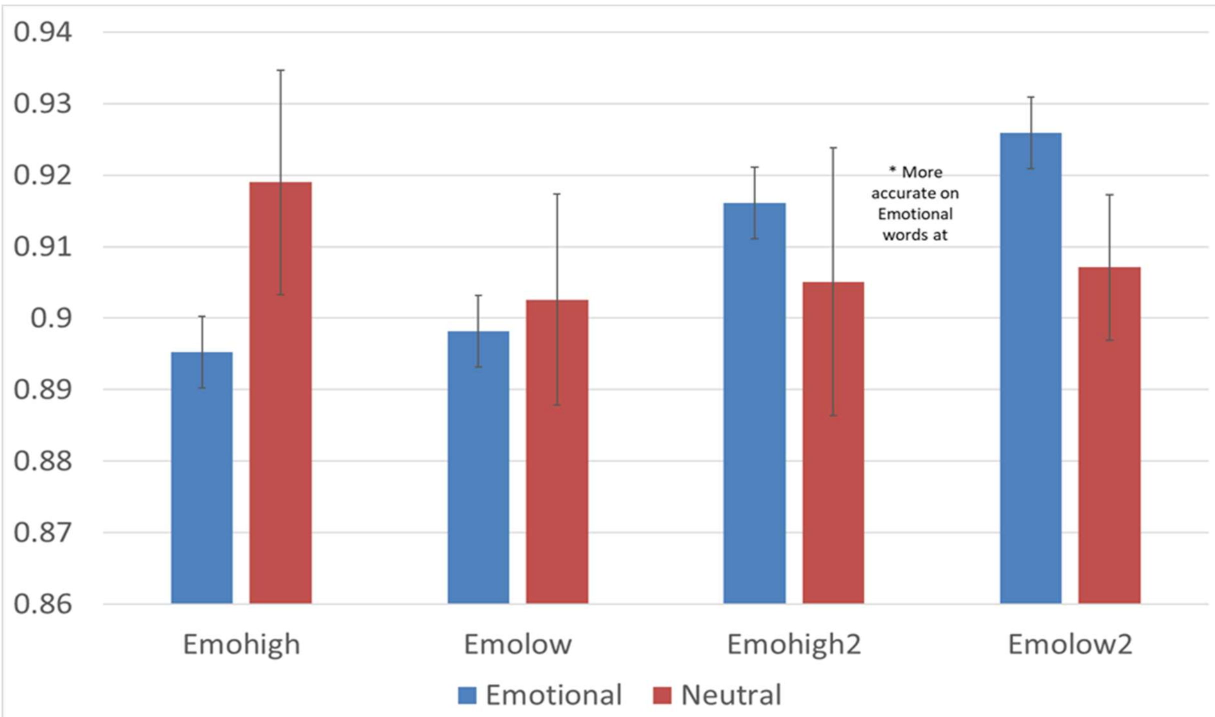

Figure 13.

The proportion of correct responses for the ES subset of participants in Experiment 2. Participants were more accurate on emotional words in the second repetition. Note that the error bars represent between subject variance.

Discussion

Our selection criteria for the ES was again successful at creating a subset of participants that demonstrated the ES, however, Experiment 2 did not find the block-wide proportion manipulation effect that was seen in Experiment 1. In fact, participants demonstrated an ES across both block repetitions with no apparent variation according to our block content manipulation.

The repetition of stimuli from the first block presentation did not impact proportion manipulation effects. There was only a trend for participants to be faster on the repeat block presentations indicating that the ES remained strong throughout the experiment. Although, it should be noted that our method of selecting participants who demonstrated the ES in the first block repetition versus the second block repetition may have obscured observation of a learning effect.

It is difficult to make a claim about block order given our lack of an effect of our proportion manipulation in Experiment 2. What we can say is that block order did not interact with our proportion manipulation in this experiment although we acknowledge that our sample size for this comparison was small. Whether this is because it is not an important factor to consider, or there was no effect to interact with is difficult to say. There were a few general learning effects that differed based on block order which support our inclusion of this variable in our analysis.

One potentially important difference between Experiment 1 and Experiment 2 was the presence of the equal block of trials. Part of our reasoning for removing the equal block was to assess whether block order effects may have contributed to the block-wide proportion manipulations found in Experiment 1. The inclusion of block order as a variable had no bearing on the size of the ES or its proportion manipulation effects. In addition, Experiment 2 failed to find evidence for a proportion manipulation of the ES. As the main difference from Experiment 1 to 2 was the presence of additional experimental context in the form of an additional block, it is possible that the additional context of the equal block may have supported learning of the differing proportions and thus, supported an attentional modulation effect. By providing additional distinctive blocks, it's possible participants may have been alerted to differences between the blocks. The block wide manipulation may be particularly difficult to pick up on in a proportion manipulation of the ES as we use a large selection of different emotional words. Thus, participants need to become sensitive to the appearance of additional emotional interference in a block and make adjustments instead of encountering a small subset of incongruent S-R response mapped stimuli.

Experiment 3 incorporated 92 additional emotional and neutral words in order to lengthen the blocks and potentially strengthen the experimental context, which may in turn contribute to stronger attentional modulation effects as observed in Experiment 1. If context is important, lengthening the experimental blocks should result in the reappearance of proportion manipulation effects.

Experiment 3

Introduction

Experiment 1 found a proportion manipulation of the ES where an enlarged ES was found in the emohigh block. This finding seems at odds with the Stroop effect on the analogous high proportion incongruent blocks where additional control is recruited to reduce Stroop interference. Concern for the role of block order and mood induction in producing this effect led us to eliminate the equal block in Experiment 2 and repeat the blocks. Doing so allowed us to assess the possible role that block order may have played in producing the proportion manipulation effect from Experiment 1. Not only did block order fail to interact with block type or stimulus type, but the enlarged ES for emohigh compared to the emolow was absent in Experiment 2. Experiment 3 sought to investigate why the proportion manipulation effect from Experiment 1 was not replicated in Experiment 2. The possible role of the additional equal block in Experiment 1 as providing a useful context for participants to pick up on the enhanced emotional interference in the emohigh block was indicated as a possible reason for the lack of a block type by stimulus type interaction in Experiment 2. Experiment 3 sought to provide additional context to participants by lengthening the blocks and, thus, increasing participant exposure to the proportion manipulation. Experiment 3 was able to preserve the idea of novelty by using words from the equal block to lengthen the emohigh and emolow experimental blocks. This allowed us to lengthen the experimental blocks with novel emotional and neutral stimuli while preserving the proportion of emotional words in each block type (emohigh: 80% emotional, emolow: 20% emotional).

Methods

Participants

Undergraduate participants from McMaster University participated in this experiment for course credit. A total of 62 (10 male) participants took part in this study. The procedures in this experiment were approved by the McMaster Research Ethics Board (MREB) and complied with the Canadian tri-council policy on ethics.

Materials and Apparatus

The materials and methods for Experiment 3 were identical to Experiments 1 and 2.

Procedure

The procedure for Experiment 3 was nearly identical to Experiment 2 with the exception that the length of each block was increased from 92 trials to 138 trials. This was done by incorporating the words from the equal block in Experiment 1. The proportion of emotional content in the high emotional and low emotional content blocks was maintained from Experiments 1 and 2 (80% emotional and 20% emotional respectively). Again, the emohigh and emolow block orders were alternated for each participant and the block order was maintained across the second repetition. Half of the participants experienced the emohigh condition first and the other half experienced the emolow condition first. In total, there were four experimental blocks, as in Experiment 2, and the stimulus identity was the same on the second presentation. The trial presentation order was randomized within blocks.

Results

All Subjects

Reaction time

Participants were excluded from the analysis if they did not achieve an accuracy of over 70%. Using this criterion, three subjects were excluded from the analysis (n= 62). A 2 (block type; emohigh, emolow) X 2 (Repetition: 1 or 2) X 2 (stimulus type: emotional or neutral) ANOVA with the between subjects factor of block order (emohigh first, emolow first) was performed on participant reaction time to the colour task. A trend for an effect of repetition where participants were faster to respond to stimuli in general on the second block repetition was noted, $F(1,60) = 3.438$, $p = .069$. A main effect of stimulus type where participants were faster to respond to neutral stimuli indicated that participants in experiment three demonstrated the ES, $F(1,60) = 4.947$, $p = .03$. There was a main effect of block order, where participants who saw the emohigh-emolow block order were faster than participants who saw the emolow-emohigh block order, $F(1,60) = 4.158$, $p = .046$.

Stimulus type interacted with both block repetition (first vs. second set of blocks) and with block order (emohigh-emolow vs. emolow-emohigh). Examination of the stimulus type x repetition interaction, $F(1,60)= 5.819$, $p= .019$, revealed that the ES effect was larger for the first compared to the second block set repetition, $t(61) = 3.352$, $p = .001$, and that responses to emotional stimuli in the first block repetition were slower compared to emotional stimuli in the second repetition, $t(61) = 2.539$, $p = .014$, and neutral stimuli in the second repetition, $t(61) = 2.483$, $p = .016$. This suggests that some learning did occur to reduce the time to respond to emotional stimuli (See Figures 14 and 15).

A closer look at the stimulus type x block order interaction, $F(1,60) = 4.194$, $p = .045$, showed that for the group who gained experience with the emolow block first, responses were slower compared to the group who saw the emohigh block first. This was significant for neutral stimuli, $t(60) = 2.216$, $p = .03$, and trending for emotional stimuli, $t(60) = 1.811$, $p = .075$. This suggests that there may be some benefit to practicing with the high proportion of emotional words first.

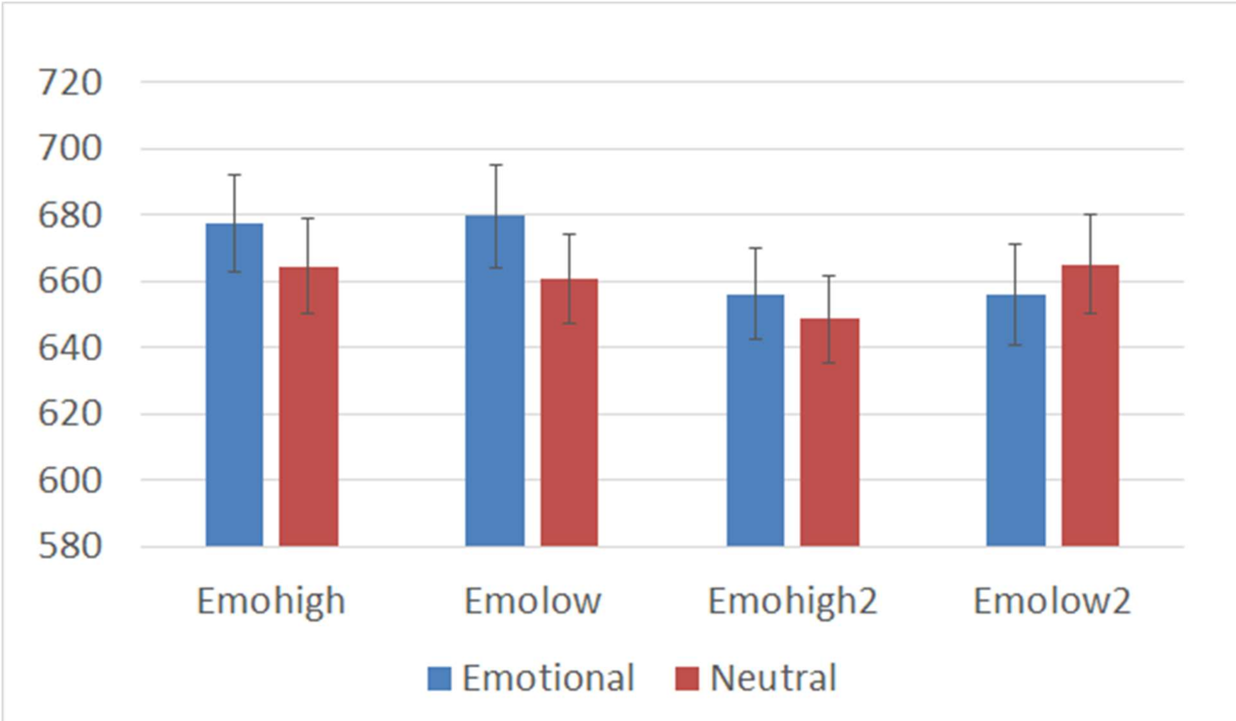

Figure 14.

Reaction time data across all subjects for Experiment 3. Participants were faster on emotional words and there was a trend for them to be faster in the second block repetition. Participants demonstrated a larger ES in the first block repetition and became faster on emotional words from repetition 1 to repetition 2. Note that the error bars represent between subject variance.

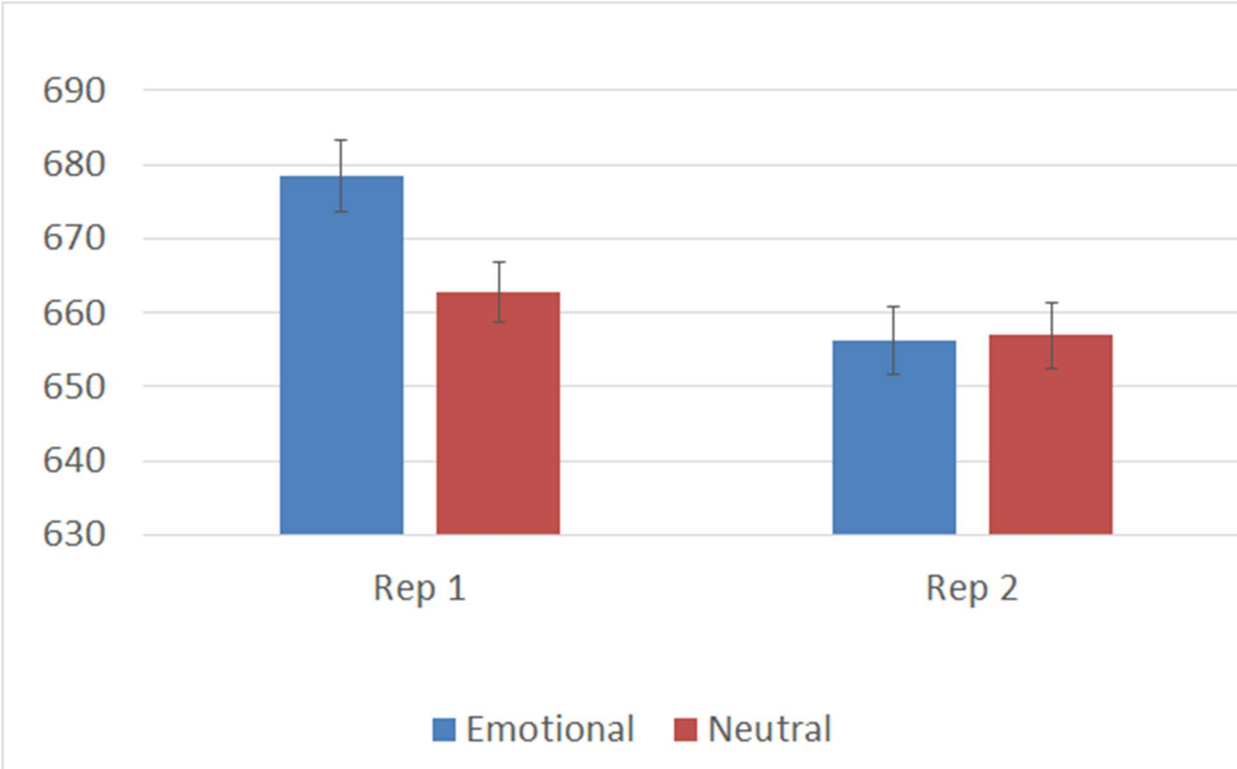

Figure 15.

Reaction time data for all subjects in Experiment 3. An ES was present in repetition 1 but not repetition 2. Participants became faster on emotional words after their first repetition. Note that the error bars represent between subject variance.

Accuracy

The same analysis was conducted on the proportion of correct responses (See Figure 16). A main effect of repetition was revealed, $F(1,60) = 5.261$, $p = .025$. Participants were more accurate in the second block repetition. In addition, there was a block type by repetition interaction, $F(1,60) = 5.348$, $p = .024$. Participants were more accurate on the second block type repetition of emolow, $t(61) = -2.98$, $p = .004$, but not the second repetition of emohigh, $t(61) = -.632$, $p = .53$. In addition, participants were more accurate on the emolow second repetition relative to the emohigh block type on the first repetition, $(t61) = -2.785$, $p = .022$, and the second repetition, $t(61) = -2.348$, $p = .022$. Participants were more accurate on the second repetition of the emolow block type than any other repetition or block type.

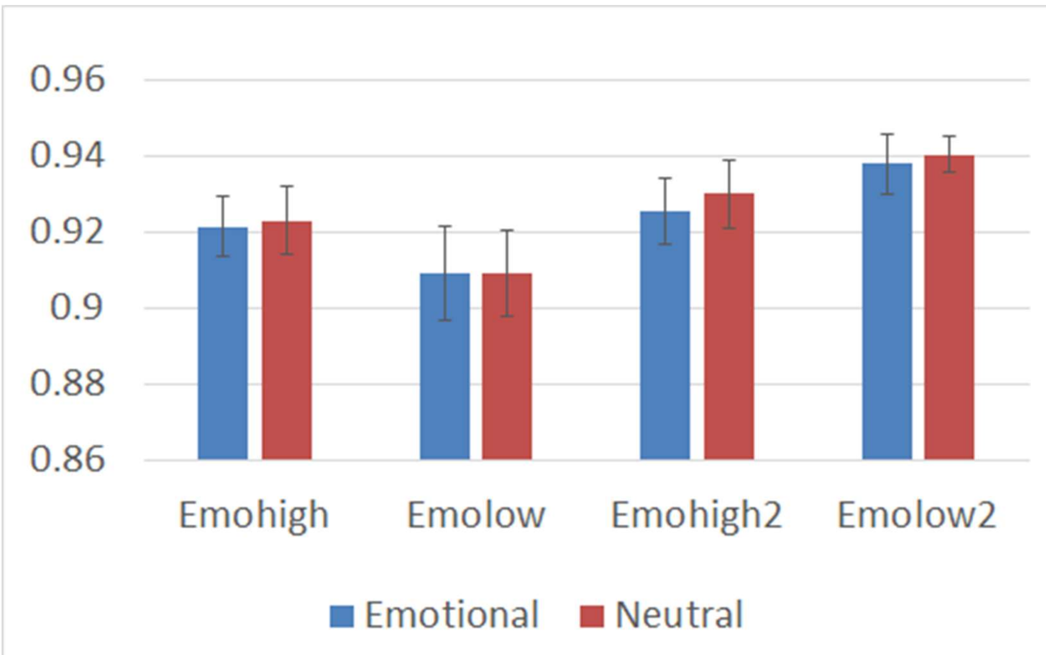

Figure 16.

The proportion of correct responses for all subjects. Participants were more accurate in the second repetition. Note that the error bars represent between subject variance.

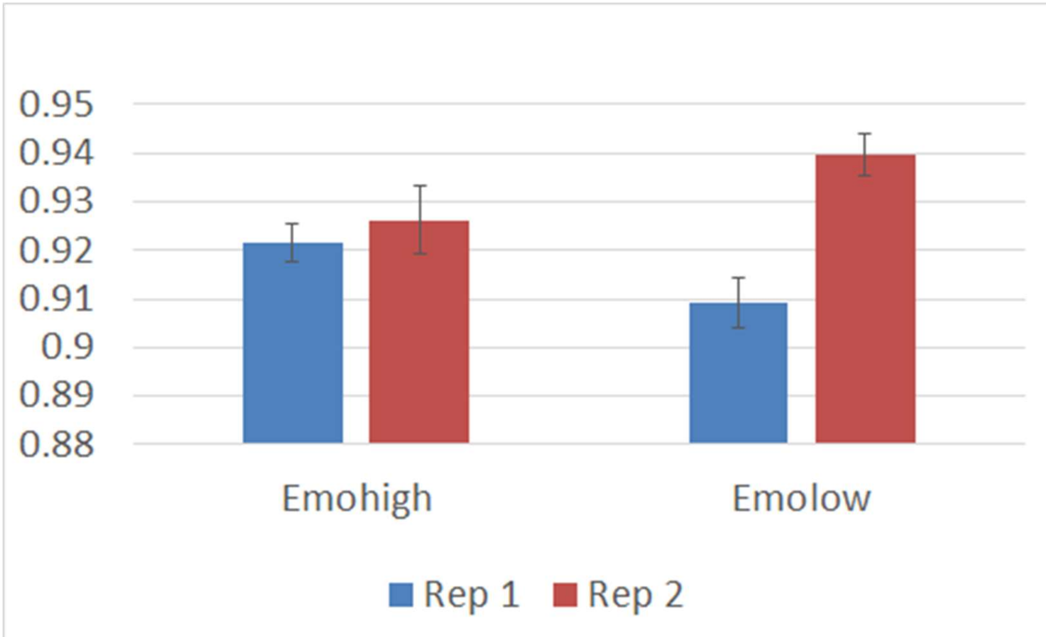

Figure 17.

The block type by repetition interaction is shown. Participants were more accurate in the second block repetition of emolow but not of emohigh. Note that the error bars represent between subject variance.

A 2 (Repetition: Rep 1 or Rep 2) by 2 (stimulus: Emotional or Neutral) ANOVA was conducted on the proportion of correct responses within each block order group in order to investigate the repetition by stimulus by block order interaction. A main effect of repetition whereby participants became more accurate on the second block repetition, was found within the group of participants who saw the emolow-emohigh block order, $F(1,30) = 5.586$ (See Figures 18 and 19).

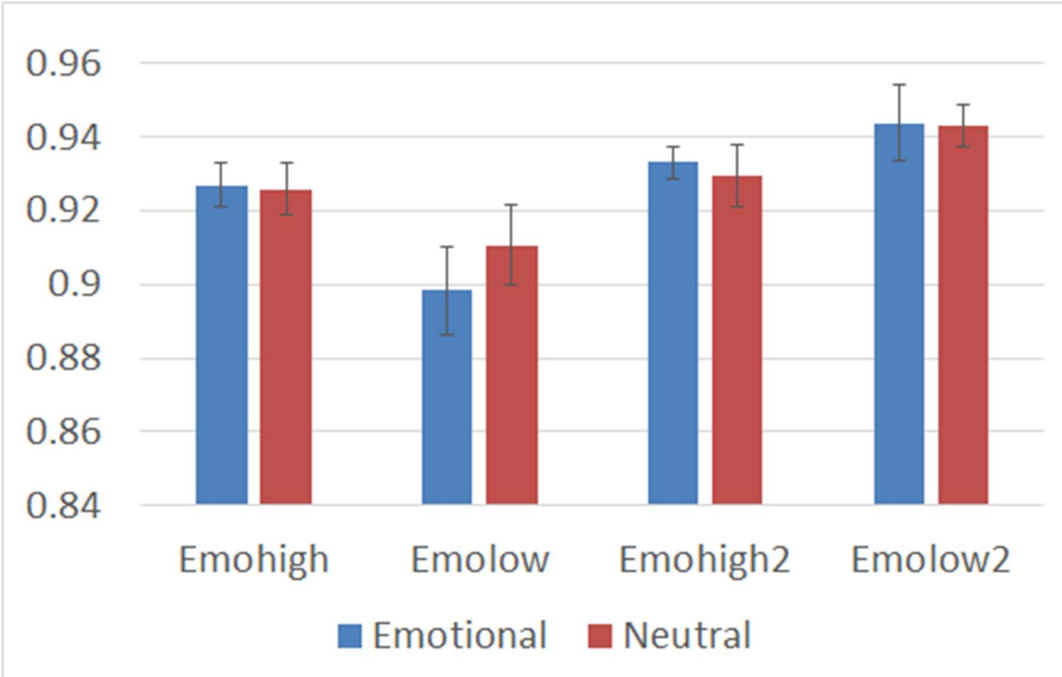

Figure 18.

The proportion of correct responses for participants who saw the emolow-emohigh block order. Participants who saw this block order were more accurate on the second block presentation.

Within the group of participants who saw the emohigh-emolow block order, an interaction was revealed between repetition and stimulus type, $F(1,30) = 6.113$, $p = .019$. This interaction was further clarified using paired sample t-tests. Follow-up analyses revealed that participants were more accurate on neutral stimuli in the second repetition relative to emotional stimuli, $t(30) = -2.077$, $p = .046$, a pattern that did not emerge during the first repetition, $t(30) = .929$, $p = .361$. Participants were also more accurate on neutral stimuli in repetition two relative to repetition one, $t(30) = -2.055$, $p = .049$ and there was a trend for participants to be more accurate on neutral stimuli in repetition two relative to emotional stimuli in repetition one, $t(30) = -1.865$, $p = .072$ (See Figure 19)

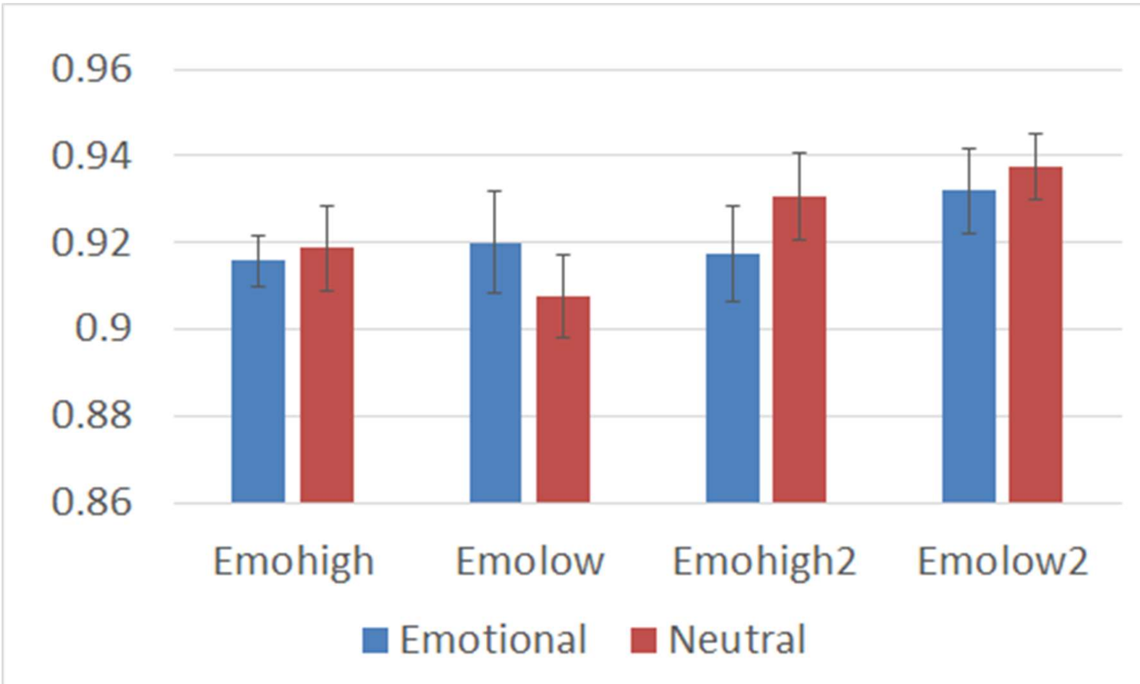

Figure 19.

The proportion of correct responses for participants who saw the emohigh-emolow block order. An interaction between repetition and stimulus type existed for this group of participants. Participants were more accurate on neutral stimuli in the second repetition relative to emotional stimuli. Participants were also more accurate on neutral stimuli in repetition two relative to repetition one.

ES Subset

In an effort to be as inclusive of participants demonstrating the ES as possible, participants were included in the analysis if they showed an ES over the first block repetition, OR the second block repetition ($n = 46$). By grouping participants this way, only those participants who did not demonstrate the ES at all during the experiment were omitted from the following analysis.

Reaction time

A 2 (block type; emohigh, emolow) X 2 (Repetition: 1 or 2) X 2 (stimulus type: emotional or neutral) ANOVA with the between subjects factor of block order (emohigh first, emolow first) was performed on participant reaction time to the colour task. A main effect of stimulus type where participants responded to neutral words faster than emotional words, confirmed that our selection of those participants showing the ES was successful, $F(1,44) = 14.888$, $p < .001$. In addition, there was an effect of repetition where participants were faster to respond to the colour of the word within the second block repetition, $F(1,44) = 5.384$, $p = .025$.

An interaction between repetition and stimulus type was revealed, $F(1,44) = 4.783$, $p = .034$. Participants were slower on emotional stimuli in the first block relative to neutral stimuli, $t(45) = 4.345$, $p < .001$, and relative to both emotional and neutral stimuli in the second block repetition ($t(45) = 3.007$, $p = .004$ and $t(45) = 3.672$, $p < .001$ respectively). Participants were slowest to respond to emotional stimuli in the first block relative to all other stimuli presentation.

An interaction between block type by repetition by stimulus type was observed, $F(1,44) = 6.834$, $p = .012$. A follow-up analysis broke this interaction down into each repetition. In repetition 1, a large main effect of stimulus type was found (the ES), $F(1,45) = 18.878$, $p < .001$, indicative of an ES effect for repetition 1. In repetition 2, an interaction between block type and stimulus type was revealed, $F(1,45) = 6.853$, $p = .012$. An ES was found in the second emohigh block repetition, $t(45) = 2.073$, $p = .044$, but not in the emolow block repetition, $t(45) = -1.362$, $p = .18$, demonstrating that the ES varied as a function of block type in the second repetition (See Figure 20).

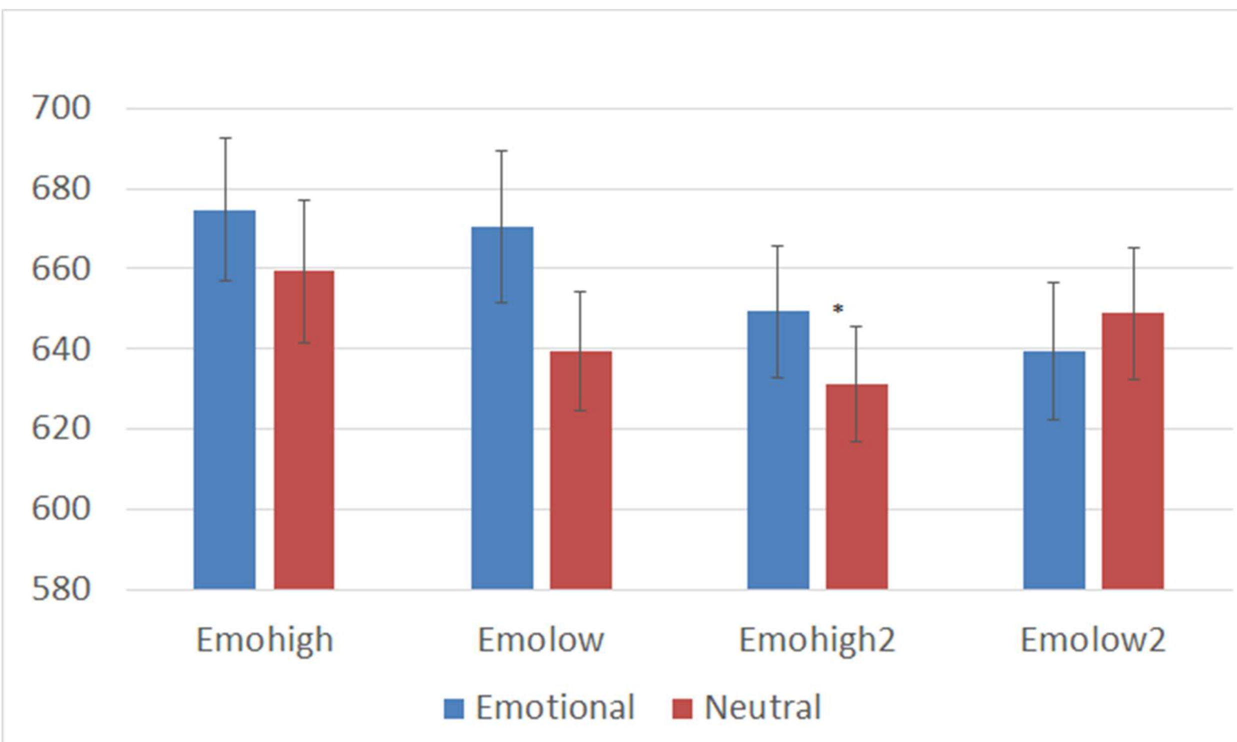

Figure 20.

Reaction time data from the ES subset of participants in Experiment 3. An interaction between block type, stimulus type, and repetition revealed a main effect of repetition for the first repetition and an interaction in the second repetition. A block type by stimulus type interaction was present in the second repetition; participants demonstrated an ES in the emohigh block but not the emolow. Note that the error bars represent between subject variance.

An interaction between block type, repetition, and block order was revealed, $F(1,44) = 4.04$, $p = .051$. Block order groups were examined separately for the factors of repetition and block type. No significant effects or interactions were found within the group of participants who saw the emolow-emohigh block order. Within the group of participants who saw the emohigh-emolow block order, a trend for an effect of block type was found, $F(1,22) = 3.591$, $p = .071$, as well as a significant interaction between block type and repetition, $F(1,22) = 5.675$, $p = .026$. Participants were significantly faster on repetition two of the emohigh block type, $t(22) = 2.414$, $p = .025$, when they had seen the block order emohigh-emolow, a result that did not extend to this group's repetition of the emolow block type, $t(22) = 1.632$, $p = .117$. There was also a trend for participants who saw the emohigh-emolow block order to be faster on the emohigh block in the second repetition as compared to their first presentation of the emolow block, $t(22) = -2.047$, $p = .053$.

Accuracy

The same analysis was conducted on the proportion of correct responses (See Figure 21). A main effect of repetition was revealed, $F(1,44)= 4.363$, $p = .025$, demonstrating that participants were more accurate in the second block repetition. An interaction between block type and repetition was also observed, $F(1,44)= 4.604$, $p= .037$. Participants were more accurate on the second repetition of the emolow block, $t(45)= -2.774$, $p= .008$, but not on the second repetition of the emohigh block, $t(45) = -.325$, $p= .747$. Participants were also more accurate on their second repetition of the emolow block relative to their first and second repetition of emohigh ($t(45)= -1.942$, $p= .058$, and $t(45)= 2.218$, $p= .032$ respectively).

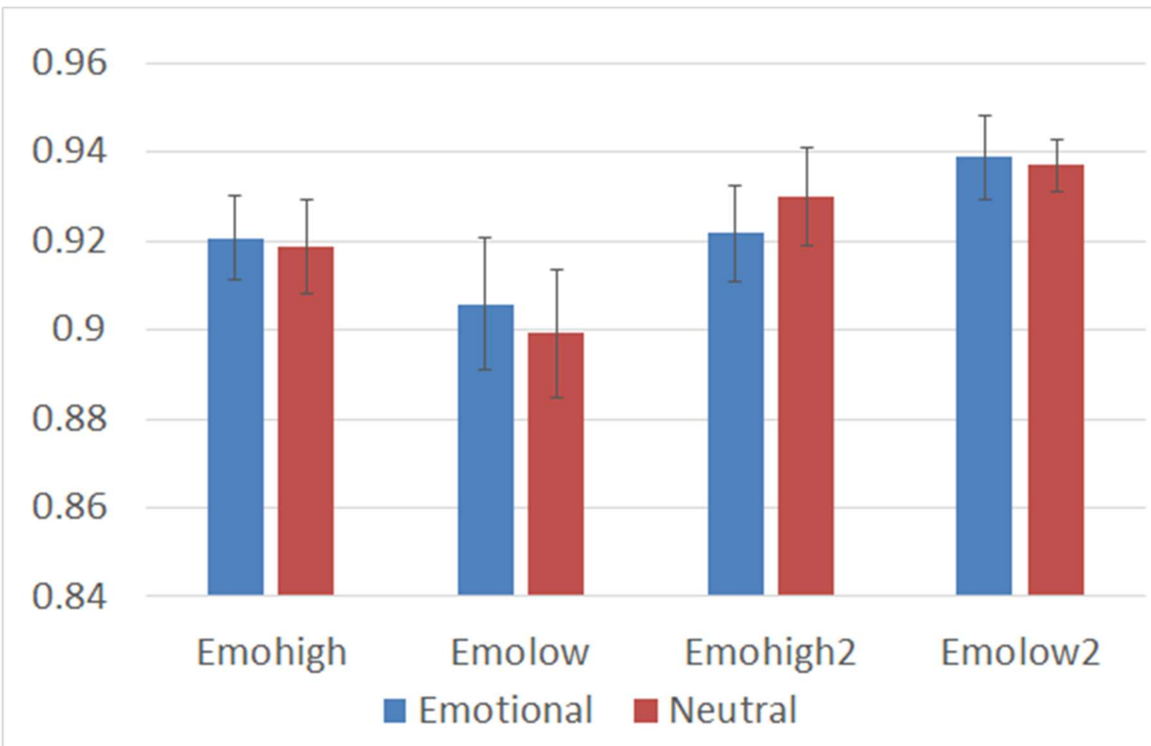

Figure 21.

Proportion of correct responses for participants in the ES subset of Experiment 3. Participants were more accurate in the second repetition. Participants became more accurate on the second repetition of emolow but not emohigh. Note that error bars represent between subject variance.

Discussion

Experiment 3 lengthened the trials per block from Experiment 2 in order to better understand the lack of a block type by stimulus type interaction within Experiment 2. Lengthening the blocks by adding in additional novel words, allowed us to examine the role of context and novelty in proportion variations of the ES. One theory we proposed for our lack of a proportion manipulation effect in Experiment 2 was that the presence of the equal block in Experiment 1 may have assisted participants with learning the experimental context where emotional content varied by block.

The critical block type by stimulus type interaction was significant for repetition 2 indicating that the ES varied as a function of our block-wide proportion manipulation. The result was a replication of Experiment 1; an enlarged ES for the high emotional content block type. Interestingly, the block type by stimulus type interaction only appeared in repetition 2. A strong stimulus type effect, representing the ES, was found in the first block presentation. This supports the idea of context in the form of additional blocks or longer blocks in producing a proportion manipulation of the ES. It should be noted that participants were also more accurate in the second repetition of emolow. This may indicate the kind of more careful responding found in high incongruent blocks of PC effects (reduced Stroop effect).

It is interesting to note that Experiment 3 revealed a significant stimulus type interaction for all the subjects who participated in this experiment. This is in contrast to experiments 1 and 2 where an analysis including all the participants did not show an ES.

The presence of more reaction to the emotional words in this experiment allowed us to include 76% of participants in our ES subset compared to 46% in Experiment 1 and 60% in Experiment 2. Whether it was the experiment itself that produced a heightened reaction to emotional words or this particular group of participants is hard to say.

Block order was again incorporated as a variable of interest but we failed to find evidence that it impacted our proportion manipulation of the ES despite the presence of a proportion manipulation of the ES. Interestingly, those who saw the emohigh-emolow block order were able to perform faster on the second repetition of emohigh, supporting a benefit for seeing a block high in emotional content first. The lack of an interaction between block order, block type, and stimulus type suggests that block order likely doesn't play an important role in ES variation as a function of proportion manipulation.

Experiment 3 supports the finding of an enlarged ES in blocks with proportionally more emotional content, although there seems to be a critical role for context and learning within this effect. Whether the emohigh or emolow block was presented first did not impact the block type by stimulus type interaction in Experiment 3, indicating that the order of practice with high vs low proportion emotional words is not crucial to produce a proportion manipulation of the ES.

General Discussion

It is well known that a proportion manipulation of congruency can influence the size of the classic Stroop effect. The impact of proportion causes the Stroop effect to be smaller in blocks with more incongruent content and larger in blocks with more congruent content (Tzelgov, Henik, Berger, 1992; Lindsay & Jaccoby, 1994). This proportion congruency manipulation of the Stroop effect is described as due to a change in control processes. In the case of a block with greater incongruence, participants are said to become more controlled and are therefore able to overcome Stroop interference on incongruent trials. In contrast, when completing blocks with greater congruence, participants are said to become more automatic which results in greater Stroop interference on incongruent trials. In contrast, the ES contains no response incongruity, instead presenting interference in the form of an emotional response to certain words. In a study of the ES, participants must overcome word-level interference to name the colour of the word but without direct response competition or facilitation from the meaning of the word itself.

As far as we know, we are the only researchers to investigate how proportion of emotional content within a block can directly influence the Emotional Stroop (ES) effect. The necessity of participants overcoming interference at the word level in order to correctly respond to the font colour of a word led us to believe that a similar attentional modulation could occur in an ES study when the proportion of interference trials was manipulated to match that of classic Stroop proportion congruent (PC) experiments. In three experiments, we demonstrate that the ES does react to proportion manipulations but it does so in a very different way from the classic Stroop. This difference appears in the form of an enlarged ES in blocks with more interference which is contrary to the implementation of additional control that has been suggested as a mechanism underlying the reduced Stroop effect in blocks that contain additional interference. In the context of the classic Stroop task, PC effects demonstrate an increase in control on blocks higher in interference stimuli, suggesting an increase of control that assists participants in behaving more cautiously to overcome the interference on incongruent trials. This additional control both slows responses to congruent trials and speeds responses to incongruent trials, producing the smaller Stroop effect compared to low-interference blocks (Logan & Zbrodoff, 1979).

A key difference between the Stroop effect and the ES effect centers around task relevance and response interference. Any word in a study of the ES is always a distraction, but greater distraction is present in the form of emotional interference for emotional words. This is highlighted by the fact that participants are faster to respond to non-word stimuli such as a string of Is (Glaser & Glaser, 1982). Unlike the Stroop, where congruent trials facilitate performance, participants in a study of the ES never have cause to attend to the word reading dimension of the word stimulus. There is never a useful attentional strategy in an ES study that involves participants attending more to the word reading dimension. Instead, it is always beneficial for participants to avoid the word reading dimension of the stimulus as much as possible.

Direct response conflict, as in the case of the Stroop effect, need not be required to promote the attentional modulations seen in PC effects. A study by Dishon-Berkovits and Algom (2000) used city-country pairings to present incongruity to participants. Even though participants never needed to respond to the city stimulus, these stimuli still produced a Stroop effect, leading to the classic PC block wide attentional modulations. Importantly, the task required a verbal response to the country word stimuli, thus reading the word was a necessary part of the task. This study demonstrates that incongruity may need to be related to the task in order to produce PC effects but it doesn't necessarily need to conflict directly with a response. It may simply be important that the interference is task relevant and that the word reading dimension is beneficial or harmful to task performance.

The possibility of making an error may be critical in producing PC effects. The anterior cingulate cortex (ACC) is known to be responsive to error as well as being an important feature in cognitive control mechanisms (Carter et al., 1998, Critchley et al., 2005, Verguts & Notebaert, 2009). Studies that contain an element of response uncertainty where an error can be made as a function of misleading stimuli, may trigger this system in a way that emotional interference cannot. Emotional stimuli may slow performance but emotional words are unable to lead to response confusion the way that incongruent stimuli do. Our experiments waited for participants to indicate a response, limiting any possibility of making an error on emotional versus neutral word trials. A way that future researchers might investigate the role of response uncertainty in producing PC effects would be to limit the amount of response time to emotional word stimuli in a proportion manipulation setting. In this case, the delay caused by the ES would be more likely to cause errors and could trigger cognitive control and attentional modulation in a similar way as is seen for PC effects.

Indeed, proportion congruency effects do occur for emotional stimuli that contain response incongruity. A study by Krug and Carter (2012) manipulated the proportion of congruent and incongruent emotional items within a block and discovered a similar adjustment of control as has been seen as that of the classic Stroop effect. Participants were presented with a face stimulus containing an emotion word congruent or incongruent with the expression on the face (the word fear presented over an image containing a neutral face would constitute an incongruent trial). The task was to indicate whether the face stimulus was neutral or fearful. Participants in this study experienced an emotional mismatch on incongruent trials, leading them to have longer reaction times to faces that were shown with an emotional mismatch. These incongruent emotional trials contained both emotional interference as well as the same type of response level interference seen in the Stroop effect and PC effects were found despite the addition of an emotional element.

One way to directly test theories of task relevancy would be to design a Stroop experiment in which emotion is incorporated (such as in the case of Krug and Carter) but where word stimuli are exclusively used. Separate conditions or groups of participants who have stimuli that are incongruent and emotional could be compared to another condition in which stimuli are purely emotional without an incongruency component. Based on the differences we have observed for PC effects and proportion manipulations of the ES, we might predict that ES stimuli containing response incongruity would demonstrate a classic PC effect while those containing emotional interference exclusively might show a modulation of the ES more similar to what we have demonstrated.

Further support for sensitivity to task relevance comes from PC studies that have restricted PC effects to contextual experiment features (Context-Specific Proportion Congruency: CSPC). In a study by Crump, Gong, and Milliken in 2006, location was able to be used as a contextual feature to restrict PC effects while shape stimuli was not. Shape stimuli predicted the proportion congruency manipulation but participants were not successful at restricting PC effects to these contexts, demonstrating a lack of this contextual feature. In a follow-up study, shape was made task relevant by asking participants to count the number of different shapes that were presented (Crump, Vaquero, & Milliken,2008). In making the informative contextual feature task relevant, the CSPC effect occurred for shape features (PC effects were found for different congruency manipulations for the shape).

When considering the reappearance of a proportion manipulation effect in Experiment 3, it may be tempting to think that there was something special about the words in the equal block from Experiment 1. This would follow since Experiment 2 did not show a proportion manipulation effect yet the incorporation of the equal block words into Experiment 3 caused the proportion manipulation effect to reappear. While this seems logical, the words from the equal block in Experiment 1 never appeared in the emohigh block where an ES was found. Instead, the equal block from Experiment 1 failed to produce a significant ES, a fact which is in line with the emolow block from this experiment. The first two blocks of Experiment 3 contain the same words from Experiment 1 but restricted to the emohigh and emolow proportion manipulations, yet an enlarged ES is only found for the emohigh block in its second presentation. While the emohigh block from Experiment 3 does incorporate words from the equal block in Experiment 1, the presence of an enhanced ES in the emohigh block from Experiment 1, and its lack of presence for the first presentation of emohigh in Experiment 3 suggest that the proportional manipulation of the ES noted in these experiments is not dependent on words from the equal block.

The between-subjects factor of block order was included as a variable for experiments 2 and 3. Despite our predictions that block order manipulation may lead to differing mood effects and, thus, different proportion manipulation effects, we did not find evidence that block order played a role in proportion manipulation on the ES or on the ES in general. It should be noted that our ability to consider block order as a variable was limited by the smaller sample size in the subset of participants who demonstrated the ES leaving us with relatively small groups with which to compare for block order effects. Given the large variance in individuals as to which emotional words generate the ES for groups, the variance across groups becomes more difficult to compare.

Future studies interested in the implications of block order for proportion manipulations of the ES could use sets of individuals for whom emotional word stimuli is self relevant (math anxious participants) in order to produce more homogenous samples. Another strategy to assess the role of mood induction as it relates to block order presentation would be to take mood measures from participants after each block completion. This data could be collected from a separate control group and used to assess the impact of block order in a separate group who is not interrupted for mood measurements. Increasing power with larger sample sizes in order to better compare block order effects would also be a useful approach that could easily be combined with mood measurements.

An explanation focused on mood induction during the emohigh block would seem to fit reasonably well with a proportion manipulation that results in an ES for the emohigh block type. Studies on mood and global-local attention including responses to threatening stimuli (Gasper & Clore, 2002; Fenske & Eastwood, 2003) have shown a narrow local focus for participants experiencing a negative mood. If participants are experiencing a block wide negative mood in the emohigh block, a more local approach could explain attention fixating on the emotional word and leading to greater emotional interference from those words on performance. The lack of a finding for an enhanced ES in the first block presentation of Experiment 3 when participants experienced a longer emohigh block than Experiment 1 would seem to argue against this interpretation. If mood induction is the source of the ES varying by proportion, we would expect to see it appear particularly strongly in the lengthened emohigh block of Experiment 3.

Another strategy for examining proportion manipulations of the ES within a general nonclinical group using a standard list of emotional words would be to have a group of participants rate the emotional words on valence on a separate occasion. After a time to delay (so as not to expose the participant to the words they will see in the experimental blocks) a participant could return to the lab to complete a customized experiment that includes the most highly rated words they had previously identified. This would ensure that the words used in a proportion manipulation were having the desired impact on the individual and would allow for a better examination of proportional manipulations of the ES that does not depend on after-the-fact participant selection.

We have highlighted the possible importance of task relevant interference in producing the type of adaptive attentional modulation found in PC effects but the question of why participants in an ES proportion manipulation were not able to adopt a better strategy for dealing with the extra emotional interference in the emohigh block remains. The answer may relate to self relevancy and its critical role in producing the ES.

First noted in fMRI studies during pre experiment rest periods, the default mode network is a network of brain activity that has been theorized to reflect introspection and self relevancy (Gusnard et al., 2001). This area reduces in activity when task demands require the application of cognitive control (Binder et al., 1999; Greicius et al., 2003), suggesting that introspection and task attention may be at odds. A number of studies on the default mode network have found that it is particularly active for self relevant stimuli, supporting the theory that it is related to introspection (For a review see: Buckner & Carroll, 2007).

As we have discussed, the ES is predicated on personal emotional reactivity to certain words. It may be possible that participants experiencing a word that is emotional to them and therefore self-relevant to them is activating the default mode network. As the activation of the default mode network may be at odds with the executive function network needed for task demands, participants in the emohigh block may have experienced an additional cost of needing to frequently switch from one mode to the other in order to correctly perform the task on emotional trials. In contrast, blocks lower in emotional content may have required less switching, allowing participants to maintain their attention to task demands and, thereby, perform more quickly on emotional interference trials. A neural network sensitive to saliency may be implicated in this switching process which would certainly fit well with our presentation of relatively novel emotional stimuli on each trial (Goulden et al., 2014).

Logically, the possibility of self relevant stimuli drawing attention away from task demands makes sense. While participants may be eager to perform correctly on the task, self relevant emotional stimuli may hold priority over correctly identifying the colour of a word in an experimental setting.

We noted in our materials that the emotional and neutral words used in these studies differed both along the dimensions of valence and arousal. Therefore, we cannot rule out the possible role of arousal in generating the effects we observed in our study. The history of arousal and emotional stimuli has shown that the two dimensions are often conflated (Thompson, Schellenberg, & Husain, 2001; Fernandes et al., 2011). In order for an emotional stimulus to be reactive for a participant, it follows that a certain level of arousal is inherent in it. In studies investigating electrophysiological responses to the ES, electromyography (EMG) measures have revealed differential reactions in participants who demonstrate the ES and those who do not, as well as defining a difference between reactivity of those high in anxiety who show the ES (Blanchette & Richards, 2013). It may be interesting to consider teasing apart these variables in future studies, but we do not feel it detracts from our results describing reactions to proportion manipulations to the effect of the ES.

In experiments 1 and 3 we found an interaction between block type and stimulus type in the form of an enhanced ES in the emohigh block. One surprising finding was the lack of an effect of proportion in the first block repetition of Experiment 2. Instead, we see an influence of proportion manipulation in the second block presentation despite the fact that the first two blocks amount to the same words presented in Experiment 1. A possible explanation for this seemingly contrary finding could be the role that the equal block provided in providing an experimental context for emohigh to appear in. Two blocks with less emotional content may have made the emohigh block from the first experiment more distinctive. Experiment 3 had one less block type that participants could use for reference to understand the differentness of the emohigh and emolow blocks. It’s possible that participants in Experiment 3 demonstrated a proportion manipulation effect only in the second block presentation as a result of difficulty in distinguishing blockwide proportion manipulations. This is not necessarily surprising given the novelty we present on every trial during the first two experimental blocks in Experiment 3.

One interesting consideration is to view the findings of Experiment 3 as demonstrating a persistence of the ES in the second block repetition of emohigh while it is eliminated in the second presentation of emolow. This explanation would fit well with the finding that participants in the ES subset of Experiment 3 showed more accurate responding in the emolow block in addition to a lack of an ES. Taken together, these findings would suggest more 'careful' responding to stimuli within this block type on its repeat presentation. This interpretation could lead us to the conclusion that the items from the first block presentation of emolow were distinctive and, therefore, less impactful on their second presentation. However, this interpretation cannot account for the findings of Experiment 1 where a lack of ES was noted in the emolow block on its first presentation.

The role of novel interference on every trial is something which PC studies simply cannot do. Due to the necessity of incorporating response, or task, incongruence into the experiment, PC studies necessitate the use of a small set of stimuli. PC manipulations are identified and attentional modulation results in changes of performance depending on the proportion of congruent stimuli within a block. The ES presents a unique opportunity for proportion manipulation research by allowing for the presentation of unique (yet similar) interference on every trial. Our current experiment does not allow us to address the relative contributions of novel emotional interference versus emotional interference on performance except to say that an effect of the proportional manipulation of the ES appeared in Experiment 1 despite using a novel emotional word on every trial. Novel words were used in this experiment to preserve the emotional impact of each word, a problem which does not exist for incongruency. Future research could consider using a subset of emotional words that participants are particularly reactive to. This would allow a proportion manipulation of the ES to be more similar to that of the stimuli used in studies of PC.

In three experiments we have demonstrated that it is possible for the ES to be manipulated as a function of the proportion of emotional words in a block. Experiment 1 demonstrated a proportional manipulation of the ES where it was present in an emohigh block but not an equal emotional content block or a low emotional content block, a result that was curiously absent in Experiment 2. Lengthening the blocks in Experiment 3 led to the reappearance of a blockwide proportion manipulation of the ES although this interaction was restricted to the second block presentation. Our results suggest a possible role of context and learning in this discrepancy. Proportion manipulations of the ES remain a useful tool for understanding the types of influence emotional interference can have on attentional strategies as well as an interesting case of examining novel interference in a blockwide interference manipulation.

Our findings show a larger impact of emotional words in blocks with more novel emotional words. One interpretation is that the novelty of seeing a new word in the first block repetition allows participants to build expectations about individual stimuli the way the ISPC demonstrates is possible for PC effects. Interference trials in emohigh blocks do not represent a risk to performance as they neither conflict nor support accurate responding. The lack of a direct impact by providing neither a conflicting response or a facilitation effect seems an important feature of attentional strategies to varying the proportion of interference words. In the ES, the word itself is inconsequential on every trial regardless of whether it is emotional or not. As a result, the ACC attentional modulation system in response to conflict may not be activated. The presence of novel negativity may instead trigger the attentional system to dedicate more resources towards the processing of words to monitor for threat.

This attendance to self-relevant emotional words may trump a participant's desire to perform accurately on a task leading to the activation of the default mode system and decreasing attention to the colour naming task. One critically important difference between the ES and experiments that contain emotional incongruity, is the presence of emotion as a distracting element to the task at hand. In the real world, we are more likely to encounter tasks we must complete with an element of emotion than we are to complete a task that requires overcoming emotional incongruity. For instance, we're more likely to have to ignore a smiling face while we compare a person's driver's license to check their ID then we are to be making a decision as to whether they are happy or sad in that image compared to how they look now. Those sorts of situations lacking in emotional congruity that require us to overcome emotional interference bound within task stimuli are important and have real life implications in our ability to adapt to task demands and modulate our attention to meet task expectations.

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