Do factors like language or word length have effects on the results of a lateralized emotional Stroop task?

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Abstract

Can we find support for either the right hemisphere or the valence hypothesis using only a lateralized emotional Stroop task? If so, what are the effects of language and word length on our results? In the present study I want to find support for either the right hemisphere or the valence hypothesis. Therefore, an emotional Stroop experiment was used. During an emotional Stroop task, emotional and neutral words are presented in different colors. The participant has to respond to the colors. Via the reaction times one can conclude about how people process emotions.

Aspects of two former studies were replicated in the present study. The words in this study have already been used in those studies. Furthermore, the present study had an additional factor. Both German and Dutch students participated in the experiment. A univariate repeated measures analyses was run on the data. No significant differences were found. The reaction times did not differ neither between emotional versus neutral words nor between the German-Dutch condition.

Introduction

The issue of hemispheric lateralization for the processing of emotional information is controversial. Two different hypotheses are formulated with respect to emotional asymmetry. The aim of the present study is to examine which hemisphere of the brain is preferentially involved in the perception of emotions.

The right hemisphere hypothesis states that the right hemisphere is dominant over the left hemisphere for processing many aspects of emotion (Christman & Hackworth, 1993). The right hemisphere hypothesis, however, was questioned by some researchers who found contrary results. Wager et al. (2003) did a quantitative meta-analysis on 65 neuroimaging studies of emotion and did not find any differences between cerebral hemispheres on emotional processing. They neither found any interactions between hemisphere as a whole and valence. But they did find a left lateralization of emotion in some brain structures and a right lateralization in others. Those data support the valence hypothesis, which is a different model of lateralization. This hypothesis suggests that the involvement of each hemisphere is determined by the valence of the emotion being processed. The left hemisphere responds more to positive emotions and the right hemisphere more to negative emotions. Davidson (1992) presented data from his electrophysiological studies of anterior cerebral asymmetries related to emotion and affective style. Those showed that the experimental arousal of positive stimuli was associated with left anterior activation while arousal of negative stimuli was associated with right anterior activation. Furthermore, Wheeler, Davidson and Tomarken (1993) argue that left frontal regions and right frontal regions are related to the experience and expression of negative and positive emotion respectively. In addition, the right hemisphere is dominant for the evaluation of all emotions.

The experiment done in this study examines the different processing of emotional material by the two hemispheres using a lateralized emotional Stroop task. During this task multiple stimuli, for example emotional and neutral stimuli, are presented in the visual half

fields. A presentation of stimuli in the left visual field (LVF) results in a representation of the stimuli in the right hemisphere, whereas a presentation of stimuli in the right visual field (RVF) results in a representation of the stimuli in the left hemisphere. If the right hemisphere is specialized for the processing of negative emotions and the left hemisphere is specialized for positive emotions, then responses should be slower for negative stimuli presented to the LVF and positive stimuli presented in the RVF. If, however, the right hemisphere is specialized in processing emotions regardless of its valence, then there should be a longer latency for stimuli presented to the LVF. Therefore, it is assumed that processing emotions takes time.

During an emotional Stroop task the experimenter measures the degree to which individuals are slower to name the color of words of concern-related (for example negative valenced) words than neutral words. Williams, Mathews and MacLeod (1996) conducted a desk research on the emotional Stroop task and psychopathology. They found out that the response latencies were usually larger for words associated with concerns relevant to the participants' clinical condition. Especially anxious patients showed those latencies. Those findings are explained as a result of attention captured by threat related words.

Only a few studies used lateralized versions of the emotional Stroop task. The study by Richards, French and Dowd (1995) was one of the first studies with a lateralized emotional Stroop task. Their experiment was conducted with high– and low trait anxious participants, who had to identify the color of threat–related, positive or neutral words. The reactions to the emotional words were slower than to the neutral words, but the researchers did not find a hemispheric effect on the valence of emotional words.

The studies done by Van Strien and Valstar (2004)[1] and Borkenau and Mauer (2006)[1] examined the effects of a lateralized emotional Stroop task on participants without pathology. Van Strien found a significant LVF/right hemisphere disadvantage. His data revealed an

[1] in the following text referred to as Van Strien and Borkenau

emotional Stroop effect in the LVF/right hemisphere, which tended to be larger for negative than for positive words.

Their outcome was more compatible with the valence hypothesis than with the right-hemisphere hypothesis. The negative interference was larger than for positive words. Under the right hemisphere hypothesis the latencies of negative and positive words should be of the same length. Borkenau, however, found different results. They did not obtain RVF/left hemisphere advantage for emotional words. Instead they found a greater interference in the LVF for negative words and in the RVF for positive words. They did not find interference for positive words in the LVF and for negative words in the RVF. This pattern is consistent with the valence hypothesis.

Table 1

Comparing the different papers

	Borkenau and Mauer	Van Strien and Valstar	Hunter and Brysbart	Current Study
Word length	M=7.3	M=4.4	M=4.5	M=6
Use of frequency controlled?	no	yes	yes	no
Visual angle	More central edge=2.7° Distal edge (max)= 5.3°	More central edge = 1.5° Distal edge= 5°	More central edge=0.95°- 2.39° Distal edge=3.82°	More central edge = 2.0° Distal edge (max)= 4.9
Distance to screen	Ca. 50 cm	Ca. 50cm	Ca. 50cm	Ca. 70 cm
Font	24- Times New Roman	18- Swiss roman	?	12- Calibri
Colors used	Blue, red, green, yellow	Blue, red, green, yellow	Blue, red, green, yellow	Blue, red, green, yellow
Presentation duration	150ms	180ms	200ms	200ms
Masked?	no	no	yes	yes
Bilateral stimulus	no	no	yes	yes

Table 1 (continued) *Comparing the different papers*

	Borkenau and Mauer	Van Strien and Valstar	Hunter and Brysbart	Current Study
Number of observations	480	96	192	480
Response style	Keyboard, fingers of the right hand	verbal	verbal	Keyboard, fingers of both hands
Feedback?	yes	no	no	yes
Number participants	125 (62 female)	54 (all female)	26 (17 female)	52 (31 female)
Handedness	112 right-handed, 13 left-handed or without clear-preference	right-handed	left-handed	47 right-handed 5 left-handed

The two studies shall be used as a basis for the present study. In addition, to those studies the paper by Hunter and Brysbaert (2008)[2] was used to make the experiment more reliable. They propose many thoughtful aspects. In their paper they try to "establish the ideal parameters for visual half field (VHF) experiments to measure language dominance … and compare laterality indices". Their experimental design as well as the experimental designs of Borkenau, of Van Strien and of the current study are being compared in Table 1.

In the following, the three studies will be compared and discussed in order to design the current experiment. Therefore, the differences in the experimental design shall be reviewed concerning word length, number of observations, response styles and selection of participants. The words used by Borkenau are longer than those words used by the other two studies. Longer words imply a larger distal edge. Therefore, they are more difficult to identify. Also a different and smaller font could be used, which makes them more difficult to

[2] in the following text referred to as Hunter

recognize. However, the participants' task is to recognize the colors and not to identify the words. The participants do not necessarily have to be conscious about the meaning of the words. Therefore, trials with longer words display more color space. Also, the word, which is not identified, does not interfere with the color recognition. A longer word could facilitate the color determination. In languages read from left to right, a RVF advantage is easy to observe because of the reading direction. The reading direction is one of the reasons why the RVF advantage is larger for long words than for short words (Ellis, 2004). Therefore, differences in word length might lead to different results and should be controlled. A study should use either long or short words. In some studies frequency of word use was also controlled. If an experiment has words which have different frequencies of use, those words could cause more or less interference on the reaction times. Words which are used less often are likely to be recognized to a lesser extent. Those words invoke less interference in the hemisphere than words which are used more frequently. Those latencies, however, are not invoked by the valence of the word, but by different frequencies of use. Therefore, only words with an equal frequency of use should be used.

Another aspect of concern mentioned by Hunter is the number of trials used in the experiment. According to them a well designed VHF task should contain an "acceptable" number of observations (>150). This is due to supposable practice effects in VHF advantages. Table 1 shows that Van Strien has less than 100 trials and might therefore not have enough trials. Differences in latencies between the first trials and later trials could be caused by the novelty of the task. After sufficient trials such an effect could decrease.

Furthermore, Hunter suggests to use a bilateral stimulus presentation. She refers to Boles (1994), who obtained a great RVF advantage using a bilateral stimulus. Hunter presumes that the reason for those better results is that the LVF stimulus has to compete with the RVF stimulus, which is easier when the target arrives in the dominant hemisphere and the competitor in the non–dominant hemisphere than in the reverse situation. Researchers should limit the presentation duration to 150 ms (with a bilateral display the

stimulus can be presented for up to 200 ms) in order to avoid eye movements towards the target. Moreover, a unilateral stimulus is a strong attention catcher and can lead to express saccades. Express saccades are reflexive eye movements to a stimulus onset which can be initiated within a time period of about 100ms (Fischer, 1984). Van Strien and Borkenau did not use a bilateral stimulus. Their results could be biased by express saccades.

The stimulus should be presented at least 1° of visual angle outside the fixation location to ensure unilateral projection. Without a unilateral projection, the stimuli could interfere with the fixation cross or the counter stimulus. Also, the stimulus should be replaced by a patterned mask at the offset. This prevents any afterglow effects on the screen and afterglow effects on the retina of the eye. Both studies controlled for a unilateral presentation of the stimuli.

Van Strien and Hunter let their participants respond verbally, whereas Borkenau let his participants respond by pressing keys with their right hand. It is demonstrated that most people have a left language hemisphere dominance (Josse and Tzourio-Mazoyer, 2004**)**. The emotional Stroop task assumes that people in some way recognize the presented words. This means that the left hemisphere is activated during the task. Additionally, in participants', who respond verbally to the stimuli, the left hemisphere is in any event active. Therefore the left hemisphere advantage might be enforced. By responding with the right hand, on the other hand, one might expect a right hemisphere advantage. To prevent a hemisphere advantage or an amplification of the hemisphere advantage one should use both hemispheres equally. In the current study, the participants have to respond with both hands. Both hemispheres are activated, there should be no hemisphere advantage due to the response mode.

The three former studies also selected their participants differently. Van Strien only allowed females to participate, whereas Hunter and Borkenau had male and female participants. There are studies which obtained gender differences in emotional activity. Lithari (2010) shows in his study that females exhibit greater negativity than males, but only

for unpleasant stimuli. Van Strien might be correct by choosing female participants. He might get stronger latencies for negative words. However, his study cannot be generalized over the whole population. His sample does not mirror the normal population structure.

Those considerations were taken into account in the design of this experiment. This should obtain more reliable results about the lateralized hemispheres issue. To examine the impact of language the experiment shall be taken by German students as well as by Dutch students. Words from the original German (Borkenau, 2006), the original Dutch (Van Strien, 2004) experiment and a translated version of the words shall be used in the current study. Using those words, the impact of the word length can be controlled. The current study shall be taken by female and male participants. The results might be less significant than the results obtained by Van Strien, but the results are more reliable and can easily be generalized. This study does not have a biased sample. The subjects in the current study have to respond to the colors by pressing keys on a keyboard. To avoid a bias of one of the hemispheres, the participants had to press equally often with the left or right hand. As suggested by Hunter a bilateral stimulus is presented to avoid express saccades. The stimulus is masked to prevent an afterglow effect. A left hemisphere lateralization of language occurs more often in right-handed participants (Szaflarski, 2008) than in left-hand participants. This might result in a RVF advantage by right-handed participants. The participants' handedness was assessed to correct for these advantages.

This lateralized emotional Stroop task aims to elucidate where emotional stimuli are processed. Van Strien was criticized for his choice of participants, number of trials and the chosen response mode. The experiment done by Borkenau had, as the review shows, a better design. The hypotheses are based on the outcomes of their study. We therefore assume that the results support the valence hypothesis and not the right hemisphere hypothesis. This implicates that more time is needed to react to unpleasant words in the LVF and pleasant words in the RVF than to react to unpleasant words in the RVF and pleasant words in the LVF. The words used in the study by Van Strien were significantly shorter than

in the Borkenau experiment. The current experiment uses words from both studies. If there is an effect of word length this should be confirmed by the current design. Furthermore, the current experiment shall be done by German and Dutch students. This will demonstrate that language or rather origin does not influence the results.

Method

Participants

Fifty-two students from Twente University and Saxion University in Enschede participated in the experiment. They were either given course credits or took part voluntarily. There were 30 Dutch participants and 22 German participants with a mean age of 22.28 years (SD = 2.73) who got tested for normal color vision. Of all participants 31 one were female, thereof 17 were Dutch females. From the 21 male participants were 15 Dutch. The participants also had to fill in a questionnaire about their handedness. 47 participants stated to be right hander and the others to be left hander.

Informed consent was obtained from all the participants. The study was approved by the ethics committee of the Faculty of Behavioural Sciences from Twente University.

Apparatus

Stimulus presentation, timing and data collection were achieved using E-prime 2 (Psychology Software Tools, Inc., http://www.pstnet.com/) on a standard Pentium # IV PC. Visual stimuli were presented on a 17-inch Philips 107T5 display.

Stimuli and task

The stimuli used during the experimental run were a selection of 60 words (20 positive, 20 negative and 20 neutral) which were already used during the experiment by Van Strien and Valstra. Those words were controlled for frequency of use. Those 60 words were

all used in the experiment by Van Strien. Borkenau used more words, but a selection was made to get an equal number of words from both experiments. Sixty words (20 positive, 20 negative and 20 neutral) from the experiment by Borkenau were chosen and used in this experiment. Those words, however, Borkenau did not control for frequency of use.

There were two experimental groups. The Dutch participants received the original words from the Van Strien experiment and a translated version from the words used in the experiment by Borkenau. The German group received the original words used in the experiment by Borkenau and Mauer and a translated version from the original Dutch words. Moreover, the original Dutch words were matched for word length and had an equal word length (M 4.6, range 4-6 letters) in both groups. The original German words were also matched for word length and also had an equal word length (M 7.4, range 5-11 letters) in both groups.

Each word appeared only once in blue, red, green or yellow on the left or right side. Out of 960 trials 480 trials were randomly chosen. First of all this number of trials was chosen to make the experiment more comparable to the Borkenau experiment. Secondly an experiment with 960 trials seemed to be too protracted for the participants. The words were displayed in 20-point Calibri font on a light-gray background. The center of each word appeared at 4.5° (5.5 cm) of visual angle from fixation. Participants sat approximately 70 cm in front of the computer screen, but this was not strictly controlled. They had their middle and index finger of their left hand and the index and middle finger of their right hand on the C, V, B, and N keys of the keyboard. Each key corresponded to one color (C to blue, V to red, B to green and N to yellow). The arrangement of the colors was made visible to the participants during the whole experiment by putting stickers on the bottom end of the computer screen.

In both conditions the experiment started with a practice phase which contained 24 neutral words. They were not further used during the experiment. Each trial started with the presentation of a black cross in the middle of the screen for 1000ms (see Figure 1). The cross also remained on the screen during the presentation of the stimulus. The stimulus was

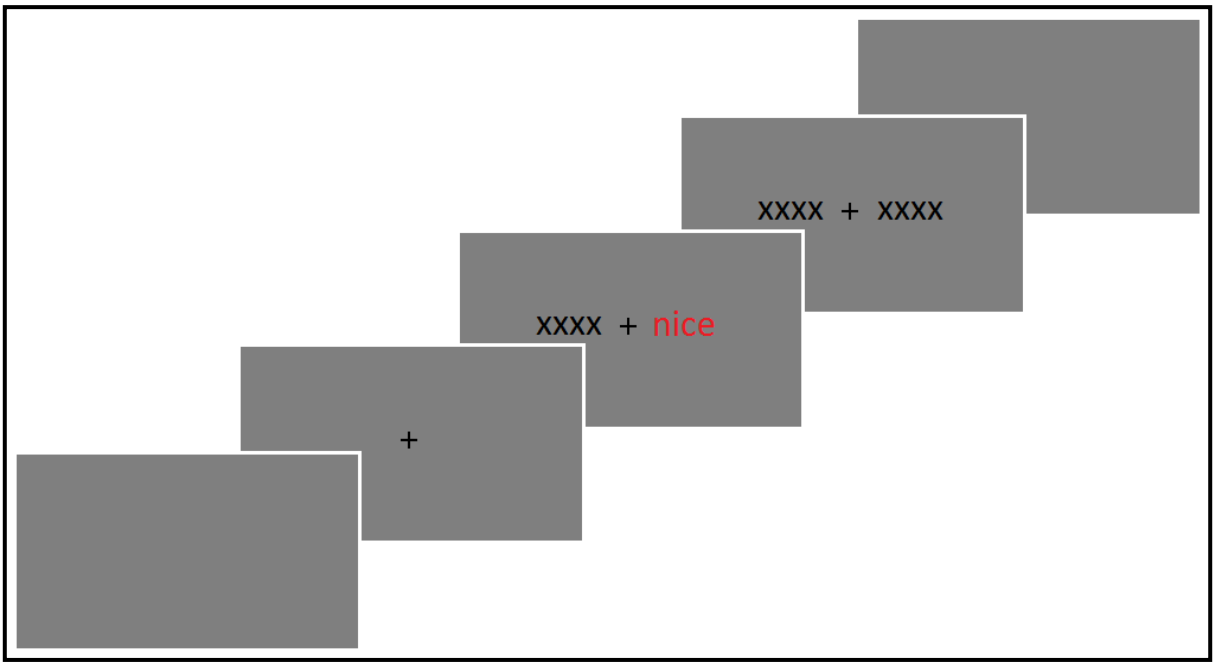

Figure 1. *Example of a trial as it was displayed on the monitor.*

randomly presented on either the left or the right side of the black cross. With the presentation of the stimuli the reaction time of the participant was measured. To avoid eye-movements of the participants black x-es were shown on the opposite site of the stimulus.

The number of x-es was dependent on the number of letters the stimulus-word contained. This stimulus vanished after 200ms and was immediately followed by black x-es on both sides. The number of x-es was still equal to the number of letters the word contained. The x-es remained on the screen until the participant had pressed on one of the keys according to the color of the presented word. The participant had two seconds to react. If the participant exceeded the time limit, the reaction was measured as false.

After a correct reaction the screen cleared for 400ms. Then the next trial started. After a false reaction the participant immediately got feedback by an error-message in the middle of the screen with the word false (according to the condition “fout” or “falsch”) which remained on the screen for 400ms. Afterwards, the screen cleared for 400 ms and the next trial started.

The test-phase contained four blocks. Each block contained 120 trials, which were chosen according to the random principle and occurred only once during the experiment. The design of the trials was same as during the practice trials.

Procedure

After being welcomed by the experimenter, the participants signed the informed consent forms and were instructed to sit in front of the computer. They were asked to view some pictures to screen for color blindness. Then their handedness was recorded. Afterwards, the participants received instructions via the screen for the task and were asked to react as correctly and quickly as possible after the presentation of the word. Also, they were explicitly asked to fixate on the central cross.

After the practice trials and after each block a short break was provided in which the participants had the possibility to relax. The length of the break was determined by the participant. Each block lasted approximately 7 minutes and the whole experiment took about 45 minutes. The sequence of the words and spatial occurrence was random.

Data Analysis

The data of this experiment were merged with E-Prime E-Merge and exported with E-DataAid©. The data were then analyzed by use of SPSS 16.0 for Windows. Univariate repeated measures analyses were run on the data.

If a wrong key was pressed, a key was pressed too early (before the stimulus was presented) or a response occurred more than 2000ms after the stimulus offset, the reaction time of the trial was not analyzed (5.46% of all trials). The mean RTs and error percentages were evaluated statistically by analysis of variance (ANOVA) with repeated measures. Therewith outliers were excluded, which was also done in the studies by Borkenau and Mauer. The dependent variable was the reaction time.

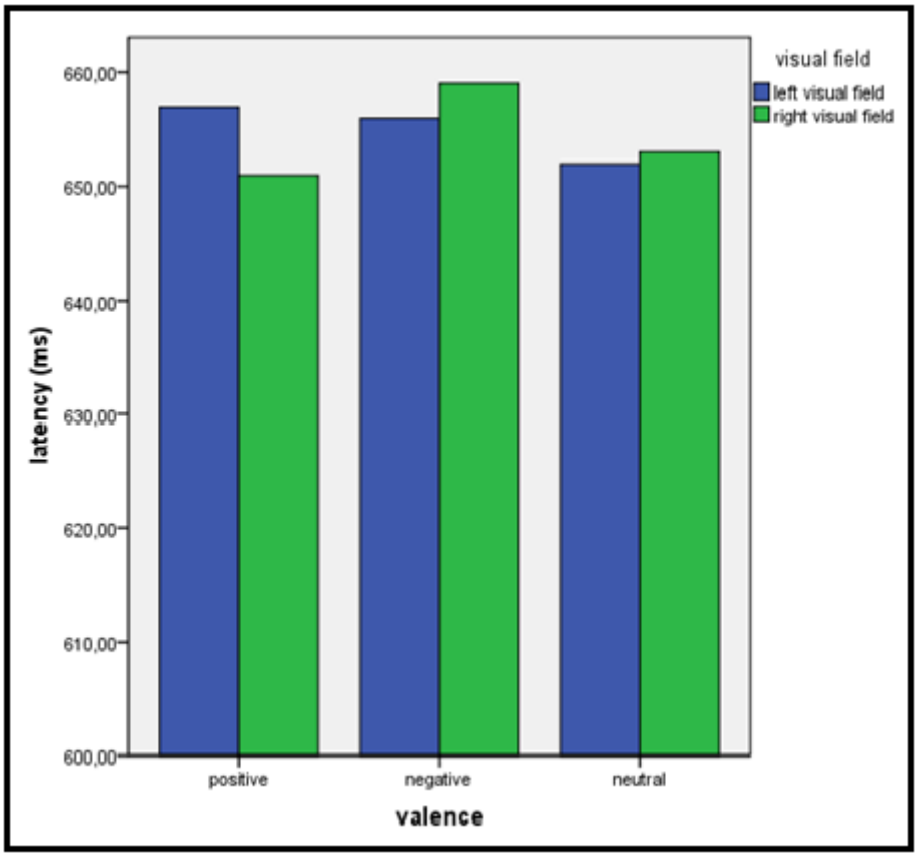

Figure 2. Mean latencies for pleasant, unpleasant and neutral words.

The mean latencies (measured from stimulus onset) for pleasant, unpleasant and neutral words presented in the LVF or in the RVF are reported in Figure 2. The data were further analyzed with the factors emotional valence, visual half field, the hemisphere hypotheses gender and country. First, a 3x2 analysis of variance with the within-subject factors valence (pleasant, negative, neutral) and visual-field (left, right) did not show a main effect of valence, $F(2, 102) = 1.33$ and $p = 0.26$. There was neither a main effect on the visual field, $F(1, 51) = 0.03$, $p = 0.86$ nor a significant Valence x Visual field interaction, $F(2, 102) = 1.15$, $p = 0.32$. There was no main effect of Country, $F(1, 50) = 0.05$, $p = 0.83$, and the Valence x Country interaction $F(2, 49) = 0.6$, $p = 0.69$, and the Valence x Visual Field x Country triple interaction $F(2, 49) = 1.22$, $p = 0.33$ were not significant. Mean latencies for positive, negative and neutral words were 654, 657 and 652 ms respectively. Mean latency per key on the keyboard was for c = 654ms, for v = 688ms, for b = 676ms and for n = 606ms.

To test the right hemisphere hypothesis and the valence hypothesis, two orthogonal comparisons were run. Since the right hemisphere hypothesis states that the right hemisphere is dominant over the left hemisphere for processing emotions, latencies for emotional (positive and negative) and neutral words were compared to test this hypothesis. To test the valence hypothesis, which suggests that the involvement of each hemisphere is determined by the valence of the emotion being processed, latencies for positive and negative words were compared.

The data for pleasant and unpleasant words were combined to test the right hemisphere hypothesis. A 2x2 analysis of variance with the within-subject factors emotionality (emotional/ neutral) and visual field (left/right) was run. A significant effect of emotionality could not be detected, $F(1, 51) = 1.76$, $p = 0.19$, of the visual field $F(1, 51) = 0.003$, $p = 0.96$ and no interaction effect was found either $F(1, 51) = 0.29$, $p = 0.59$. The data did not support the right hemisphere hypothesis.

To test the valence hypothesis a 2 x 2 analysis of variance with the within-subject factors valence (negative/positive) and visual field was run. The neutral words were not included. This analysis did not yield any significant effect of valence $F(1, 51) = 1.05$, $p = 0.31$, nor of the visual field $F(1,51) = 0.2$, $p = 0.65$ nor an Valence x Visual Field interaction effect $F(1,51) = 1.79$, $p = 0.19$, either. The data did not support the valence hypothesis.

An analysis of variance was performed on the factors gender on valence. The factor gender had no significant effect on valence; $F(2,100) = 0.06$, $p = 0.94$. An analysis of variance was performed on the factor word list (words used by Van Strien vs. words used by Borkenau). The factor had no significant effect $F(1,51)= 1.12$, $p = 0.29$.

Also a 2x2 analysis of variance with the between-subject factors valence and word length (short, medium, long) was run. No significant main effect of length was found, $F(2, 102) = 0.71$, $p = 0.49$. There was no interaction effect found either, $F(4, 204) = 0.34$, $p = 0.67$.

Discussion

The major impetus for starting this research was to find support for one of the lateralized hemisphere hypothesis. Generally speaking, the experimental design of the current lateralized emotional Stroop task was based on a literature review. The aim was to construct a more reliable experiment. As a result of the suggestions made by Hunter, the studies of Van Strien and Borkenau showed some flaws in their designs. The review showed that Van Strien used an insufficient number of trials. Besides, his choice of response mode and selection of participants was questionable. Van Strien and Borkenau presented unilateral stimuli and did not control for express saccades. In addition to a reliable design the current study aimed to determine whether there is an effect of word length and of language.

However, the results of the current study did not show a significant interference on any experimental condition. Neither a lateralized effect nor even an emotional Stroop effect was found. This was inconsistent with earlier studies (McKenna 1995, Van Strien 2004, Richards 1995). Those studies found at least longer latencies for words with emotional value in contrast to neutral words. The present study did not find those latencies. Therefore, we should look at the differences in the designs of the experiments and the possible influences those differences have on the current results.

The main methodological difference between the present experiment and the experiments done by Borkenau and Van Strien is masking the words. In contrast to those studies, the stimuli of the current study remained on the screen for 200ms and then were masked by x-es. Masking those stimuli prevented an afterglow effect of the screen as well as an afterglow effect on the subject's retina. We therefore presented the words about 50ms longer than in the original experiments. The results suggest that masking the stimuli prevented deeper semantic processing. One can assume that the emotional value did not get processed same as in the earlier studies. Even though the duration of the stimuli presentation should be enough (word recognition also by presentation duration of 100ms,

Pammer 2004) to recognize the words, it seems as if it would take longer to process the emotional value of the words. The current design prevented deeper semantic processing of the words. This study shows that studies by Borkenau and Van Strien relied on the afterglow-effect. The actual stimulus presentation has to be longer than described in those studies. To determine the actual presentation time one should mask the stimuli. A pre-test might have been expedient. In that case, the recognition of the words might have been controlled.

Another explication for the results could be found in the different response styles. While the subjects in the Van Strien study had to respond verbally and the subjects in the Borkenau's study had to give their responses with the fingers of the right hand, the subjects in the present study had to respond with the fingers of both hands. Verbal responses often cause left hemisphere activation and motor processes with the right hand cause right hemisphere activation. The response modes of both studies activated one hemisphere more than the other. This could explain the different results obtained by both studies. The current experiment activated both hemispheres equally, which eventually prevented a significant effect.

Still another cause could be that the number of participants was too small to obtain significant results which were expected. Borkenau had 125 participants, whereas Van Strien had 54 participants. The number of participants by Van Strien is comparable to the present study. However, those participants were all Dutch females. Females exhibit greater negativity than males for unpleasant stimuli. The current study included both female and male students. Therefore, the number of participants might be too small. The differences in hemispheric lateralization were not significant. The aim was to conduct the experiment by 60 participants. However it turned out to be more difficult to gather enough participants, because of the time limit.

We have already mentioned that the three studies required the participants to respond in different ways, which could explain the differences in reaction time. Furthermore, the colors could influence the reaction times. Even though we tried to use the same colors as

used in the former studies, the participants mentioned the words written in yellow were difficult to read/see. The data, however, showed that it was not the color ‘yellow’ which took longer but the colors ‘red’ and ‘green’. More likely, not the colors are of influence but the location of the keys the participants had to press. The inner keys took longer than the outer keys (c = 654, v = 688, b = 676, n = 606). This can be due to shortage of space for the hands. The four keys which were used during the experiment lay adjacent to each other. An additional factor could have been the angle in which the words were presented to the participants. Other studies (e.g. Borkenau, 2006 and Van Strien, 2004) let their words appear at a maximum edge of about 5° (4.37cm). The words from the present study also had their maximum edge at that angle, but the participants sat 20cm further away from the screen than the participants in the Borkenau experiment. Another explanation for the longer latencies and non-significant results might be the angle and the distance to the screen. Furthermore the distance to the screen was not strictly controlled. It is possible that the subjects could not read the whole word. Afterwards it was clear that a pre-test, which should have checked for visibility, had been necessary. Beforehand, conducting a pre-test was not considered because of the similarity to the Borkenau experiment.

After careful consideration of possible hassles in the method employed in the experiment, I suggest to modify the current test design. The duration of the stimulus presentation should be prolonged. Moreover, the angle in which the words are presented should be changed. The angle, which is used by Borkenau, should be maintained. They used longer words and still obtained significant results. A pre-test to check word recognition and visibility should be administered before running the experiment. Not till then one can answer the hypotheses which were generated.

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