Pupillary Responses to Emotional Valence:
A Study on Single Word Reading

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The goal of the present study was to explore pupillary responses to reading of emotional words. Participants read words of negative, neutral, and positive valence as their pupil size change was measured. The results suggest that negative and positive valence words elicit significant pupil size changes, whereas neutral words do not. Furthermore, negative words elicit a larger pupil size increase (dilation) than positive words.

Method

Participants

Five (3 female) undergraduate students (M_{age} = 22) at McGill University voluntarily participated in the experiment without monetary compensation. Participants provided verbal consent. All participants were fluent in English and four were proficient in more than one language, including French, Chinese, Spanish, and Tagalog. All participants had normal or corrected to normal vision and did not report a neurological condition.

Materials

Stimuli were selected from the Affective Norms for English Words (ANEW) verbal materials, which provide a set of normative ratings for valence, arousal, and dominance of English words (Bradley & Yang, 1999). Words were rated on a 1-9 scale with higher scores indicating more positive and stronger attitudes. Additional characterization of the words into emotional categories and gender-specific ratings were taken from Stevenson et al. 2007. Materials from the ANEW list were rated on a 1-5 scale (1 = not at all, 5 = extremely) on further dimensions such as happiness, sadness, and others.

The focus for this paper is emotional valence. Thus, twenty-eight words for the current study were selected based on the ANEW valence ratings. Word ratings at high (very positive) and low (very negative) extremes were chosen for the purpose of eliciting the strongest possible pupillary response. For the purpose of including emotionally neutral words as controls, we selected words with a median score on happiness and sadness ($M_{happiness}$ = 1.85; $M_{sadness}$ = 1.27). Experimental and control items were supplemented with a set of non-word trials in which a series of X's appeared on the screen. These trials were used to establish baseline pupil size for each participant.

Due to the strong presence of French in Montreal, French-English cognates and homographs were not included in the set of stimuli.

Apparatus

Eye movements from the right eye were recorded on a desk-mounted, video-based Eyelink 1000, sampling at 1000 Hz. Stimuli were presented on a ViewSonic 21" CRT monitor (Model G225F) at 80 Hz refresh rate, and at a screen resolution of 2048 x 1536 pixels from a

viewing distance of 70 cm. A chin rest was used to stabilize the head position. This system provides an average accuracy of 0.25° -0.5° and precision of 0.01° RMS.

Procedure

Once participants provided consent, they were asked a series of demographic and language-related questions. At the beginning of the experiment, a five-point calibration was performed, followed by a five-point validation to calculate accuracy. Calibrations below 1.0 degree of spatial accuracy were not accepted and another calibration was performed until the maximum error fell below 1.0 degree. The average error ranged from 0.02-0.45 and the maximum error ranged from 0.02-0.98. In addition, each trial was preceded by a drift correction presented as a fixation cross in the center of the screen. The drift correct was used to revalidate the calibration as well as indicate gaze position for the upcoming stimulus.

Each trial began with a single word displayed in black font centered on a gray background. The word remained on the screen for 5000 ms, after which the color changed to magenta prompting the participant to make a response on a cover task. As to ensure participants remained engaged in the experiment, a cover task was introduced. For each word, the participant was instructed to judge whether the word on the screen referred to a living or non-living thing by a keyboard press. Responses were collected but not analyzed for accuracy.

The experiment consisted of 58 trials in three conditions: 28 experimental, 15 neutral words, and 15 non-word controls. All words were presented randomly. In total, the experiment lasted about ten minutes.

Analyses

All analyses were conducted in R (R development Core Team, 2015; ver 3.2.3) using linear regression models (version 1.1-12). The dependent variable was a standardized measure of pupil size. This was calculated by subtracting the average baseline pupil size for each participant from the pupil size at each sample. Average baseline pupil sizes were based on pupillary responses to non-word trials (e.g. "XXXXX"). Thus, the dependent variable reflects a change in pupil size.

For the purpose of the analysis, the independent variable, valence, was divided into three groups: Negative, Neutral, and Positive. Successive difference contrast coding was used to find two differences between levels of valence (Neutral vs. Negative and Neutral vs. Positive) (Venables & Ripley, 2002). This allowed us to draw

conclusions about the direction and magnitude of the differences in mean pupil size change between groups. Scaled word frequency was added as an additional covariate in the model.

All assumptions of a linear regression were met (normal distribution, linearity, normal distribution of residuals, and random distribution of error).

Results

The linear regression model indicated a significant difference between the Neutral and Negative groups (b = -38.25, SE = 1.13, $p < 0.05$) as well as a significant difference between the Neutral and Positive groups (b = 19.98, SE = 1.13, $p < 0.05$). As expected, mean pupillary response to neutral words did not differ from zero (see Figure 1), suggesting that pupil size change was not merely due to reading of words. However, pupillary response to negative and positive valence words did significantly differ from zero (Figure 1). Negative words elicited greater pupil dilation than both neutral and positive words despite positive words also eliciting pupil dilation. Table 1 shows the summary statistics of mean pupil size by valence group.
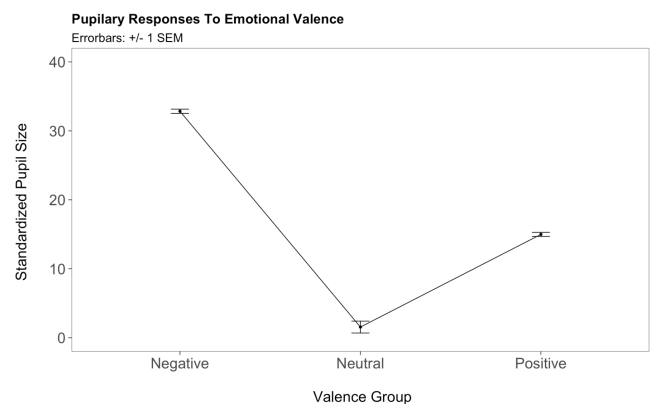

Figure 1. Raw changes in pupil size by valence group.

Table 1

Summary Statistics of Pupil Size by Valence Group

Valence Group	N	Mean Pupil Size	SD	SE	CI
Negative	161682	32.84	124.92	0.31	0.61
Neutral	12361	1.55	95.56	0.86	1.68
Positive	160875	14.98	118.14	0.29	0.58

Note. A summary table illustrating mean pupil size, standard deviation, standard error, and the confidence interval for each valence group.

Moreover, we found a significant effect of frequency on pupil size change suggesting that higher word frequencies are associated with smaller pupil size dilations ($b = -10.49$, $SE = 0.20$, $p < 0.05$).

References

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