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Females' negative affective valence to math-related words

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A B S T R A C T

Emotional perceptions of math-related information can have profound effects on attitudes about math, which, in turn, may lead to decreased math achievements. A large body of research has documented that females have less positive attitudes and more negative affectivity to math than males. This study examined emotional valence ratings of math-related verbal stimuli among adults and performed a pioneering investigation of gender differences in emotional perceptions. A random sample of 290 adults completed a battery of online affect questionnaires designated to measure the relations of various math-related words to the field of mathematics (i.e., math loading) and compared the emotional valence of these words to words known to have negative and neutral valence. Results revealed that: (1) math-related words were rated as less threatening than words with negative valence, but more threatening than neutral words; (2) math loading ratings were the strongest and most significant predictor of the emotional valence ratings of math-related words; and (3) females rated math-related words and words with negative, but not neutral, valence as more threatening than males. The study concludes that negative affective valence is linked with math-related information, especially among females, and this finding has implications for researchers, parents, and educators.

1. Introduction

In the 21st century, we are witnessing a growing reliance on technology and the fields of engineering and mathematics (Gravemeijer et al., 2017), with math proficiency considered a key factor in personal and economic success (e.g., Gravemeijer et al., 2017; Kyoung Ro et al., 2017). Yet many people are uncomfortable dealing with math-related concepts, including numbers, quantities and math-related words (Beilock & Maloney, 2015; Kucian et al., 2018). Specifically, females often express less confidence in their math ability and have more negative attitudes about math than males (Reilly et al., 2019; Rodríguez et al., 2020). They are less likely to express interest, enter, and succeed in science, technology, engineering, and mathematics (STEM) careers than their male peers (Wang & Degol, 2017; Watt et al., 2017).

Cognitive theories propose that the perception of words' negative valence (e.g., food-related words, Gilon Mann et al., 2018; negative emotional words, Palazova et al., 2013) depends on the way the individual processes threatening information (Abado et al., 2020; Goodwin et al., 2017; Öhman & Mineka, 2001). Most of the research in this domain examines the relationship between anxiety (Bar-Haim et al., 2007; MacLeod et al., 1986) or motivation (Padmala et al., 2017; Vogt et al., 2020) and cognitive processes, such as *attention* (Haft et al., 2019), including emotion regulation (e.g., Liu et al., 2019), *perception* (e.g., Sussman et al., 2016), including meta-cognition (e.g., Reinholdt-Dunne et al., 2019), and *memory* (e.g., Moran, 2016).

To explore the relationships between anxiety, motivation, and cognitive processes, experimental paradigms typically present different types of emotional words (i.e., threatening, positive, or neutral words). For example, Zhang et al. (2018) found that high test-anxious individuals demonstrated prioritized attentional allocation to test-related threatening words (e.g., "fail") with enhanced N200 amplitude (a negative-going component of the event-related brain potential which occurs at least 200 ms after the presentation of a stimulus and reflects initial shift of attention toward an emotional stimulus) and decreased late positive potential (LPP; a sustained event-related brain potential component that occurs approximately 300 ms following stimulus onset and indicates sustained engagement with a threatening stimulus). Low test-anxious individuals showed an avoidance of test-related threatening words with decreased N200 amplitude and enhanced LPP amplitude. Neither high- nor low-test anxious individuals demonstrated prioritized

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attentional allocation to neutral words (e.g., "tree"). The authors concluded that test anxiety is a situation-specific form of trait anxiety characterized by a significant initial shift of attention to a test-related threat, thus consuming valuable cognitive resources.

One important variable in the examination of the anxiety-cognition (e.g., Abado et al., 2020) or motivation-cognition paradigms (e.g., Vogt et al., 2020) is the researcher's selection of emotionally evocative words (Weierich et al., 2008). The widely used *Affective Norms for English Words* (ANEW) is a word corpus providing valence and arousal ratings of more than 600 pre-selected words rated by 100 college students (Bradley & Lang, 1999). Researchers have published the properties of words in multiple languages, including Spanish (e.g., Stadthagen-Gonzalez et al., 2017), German (e.g., Vo et al., 2009), and Italian (e.g., Montefinese et al., 2014). Some word lists are based on emotional ratings given by groups of independent judges, rather than a representative community sample (e.g., MacLeod & Mathews, 1988; Mogg & Bradley, 1998). Despite the plethora of work, there is still no actively used database of emotional words in the field of numerical cognition.

To begin to fill this gap, we collected emotional rating data for a pre-selected group of 194 neutral, emotional and math-related words. Having an emotional rating database for math-related words can be useful for developing experimental paradigms that, for example, probe information processing abnormalities in math anxiety disorders (Rubinsten et al., 2015; Suárez-Pellicioni et al., 2015) or explore gender differences. The latter was our main focus in this study. Previous work has found females are more emotionally reactive to numerical information than males (e.g., Devine et al., 2018; Hill et al., 2016), and we expected to find the same pattern.

The next section gives a review of the literature. This is followed by the study's hypotheses. We explain the method, including our development of the database of emotional words. After giving the results, we offer a conclusion. We note that our finding of a link between negative affective valence and math-related information, especially among females, has implications for researchers, parents, and educators.

1.1. Review of the literature

1.1.1. Emotional perception of math-related words

Perception is shaped by categorization processes that guide and constrain incoming information (Davidoff, 2001; Sutton & Lutz, 2019). This can be based on emotional valence and arousal (Brosch et al., 2010; Sussman et al., 2016). Valence refers to the subjective assessment of the degree of pleasant and unpleasant feelings triggered by a stimulus (i.e., threatening and non-threatening), while arousal represents the degree of activation or intensity of the response to the stimulus (Bliss-Moreau et al., 2020). Most models of emotional processing recognize valence and arousal as fundamental to the classification of affective experience (Bliss-Moreau et al., 2020; Kuppens et al., 2013). Typically, stimuli with higher positive or negative valence are more arousing (Bradley & Lang, 1999), and stimuli with a negative valence are more arousing than those with a positive valence (Citron et al., 2014).

The perceptual processing of emotional stimuli with a negative valence, specifically threatening stimuli, is generally prioritized to allow a rapid computation and analysis of the situation (Brosch et al., 2010; Öhman & Mineka, 2001; Sutton & Lutz, 2019). Individuals with anxiety disorders tend to display differential attentional allocation to threat-related and non-threat-related stimuli, a phenomenon known as attentional bias (Abado et al., 2020; Bar-Haim et al., 2007; MacLeod et al., 1986). Arousal can also be problematic; for example, the arousal evoked in the processing of emotional stimuli can have profound effects on bodily states (e.g., Bradley et al., 2001; MacIntyre et al., 2019). Thus, it is not surprising that negative valence and high arousal have an effect on academic functioning (Mason et al., 2017; Scrimin et al., 2016; Wunsch et al., 2019). Specifically, the emotional valence of verbal material has been found to affect performance in a variety of academic tasks, such as word recognition (Algom et al., 2004), lexical decision (Larsen et al., 2006), and reading comprehension (Mason et al., 2017) beyond other lexical and semantic variables (see Citron, 2012 for a review).

According to the automatic vigilance hypothesis (Pratto & John, 1991), negative stimuli capture attention because of their potentially threatening nature, and by so doing, they deplete cognitive resources. For example, higher levels of math anxiety were correlated with an attentional bias toward math-related information (Rubinsten et al., 2015; Suárez-Pellicioni et al., 2015). As a result, their speed of cognitive processing is delayed, as manifested at longer P3b latency (a positive event-related potential whose latency is related to stimulus evaluation time) during a comparison task (Huang et al., 2019).

Therefore, a more negative assessment of the valence of math-related words will affect math performance (Chang & Beilock, 2016; Rubinsten et al., 2015). In this vein, interventions focused on changing the emotional valence of the situation have been found to reduce math anxiety reactions (e.g., Jamieson et al., 2010; Jamieson et al., 2016; Pizzie & Kraemer, 2018) and improve math performance (Jamieson et al., 2010; Pizzie et al., 2020; Pizzie & Kraemer, 2018). Taken together, the literature suggests that the way math-related stimuli are emotionally perceived (i.e., valence ratings and arousal) may affect math performance.

1.1.2. Gender differences in math

Although there is no clear evidence of males' superior math skills (Else-Quest et al., 2010; Hutchison et al., 2019; Stoet & Geary, 2013), gender differences have consistently been found in perceptions of math ability, with females demonstrating more negative perceptions than males (Ganley & Lubienski, 2016; Reilly et al., 2019; Seo et al., 2019; Wang & Degol, 2017). Gender differences have also been found in attitudes and affect, with males tending to have more positive attitudes (Reilly et al., 2019; Rodríguez et al., 2020) and to express more positive affect (Devine et al., 2018; Else-Quest et al., 2010; Hembree, 1990). Numerous studies have demonstrated the unique contribution of positive attitudes to higher math achievement and better scores on standardized tests (e.g., Chen et al., 2018; Lipnevich et al., 2016). The high prevalence of males in math-related college majors and careers has been directly attributed to these gender differences (Beilock & Maloney, 2015; Hanna, 2003).

Many researchers have attempted to explain these gender differences; possible explanations include hormones and prenatal brain differentiation (e.g., Miller & Halpern, 2014), stereotype threat (e.g., Maloney et al., 2013), and societal gender stratification (e.g., Wang & Degol, 2017). Another possibility is a more negative valence assigned to math-related information among females. Females are more sensitive to negative valence stimuli (Burton et al., 2005; Gohier et al., 2013; Schienle et al., 2005), and they tend to engage emotional brain circuits rather than cognitive circuits when performing cognitive tasks (Domes et al., 2010; Koch et al., 2007; Mak et al., 2009; McRae et al., 2008).

1.2. The present study

The literature on the perceptual processing of emotional stimuli suggests that math performance may be affected by the perceived emotional valence of math-related words (Chang & Beilock, 2016; Jamieson et al., 2010; Rubinsten et al., 2015), because of the effect of emotional valence on information processing processes (Davidoff, 2001; Sutton & Lutz, 2019) and bodily states (e.g., Bradley et al., 2001; MacIntyre et al., 2019). Specifically, gender differences in the emotional perception of math-related words may explain gender differences in perceptions of math ability (e.g., Reilly et al., 2019; Seo et al., 2019; Wang & Degol, 2017), attitudes (Reilly et al., 2019; Rodríguez et al., 2020) and affect (Devine et al., 2018; Else-Quest et al., 2010; Hembree, 1990). However, to the best of our knowledge, gender differences in the perception of math-related stimuli, specifically math-related words, have not been explored.

To address these knowledge gaps, the study's aims were twofold: (1)

to compare the emotional valence of math-related words to the emotional valence of neutral and negative words; (2) to look for gender differences in the emotional valence of math-related words. We hypothesized, first, that math-related words with higher math loading ratings (i.e., perceived to be more related to math) would be perceived as more threatening than neutral words. Second, we assumed there would be gender differences in the emotional valence ratings of math-related words.

2. Method

2.1. Participants

A total of 290 participants ($M = 31.69$ years old, $SD = 9.99$ years) participated in the study. This random sample of participants included 106 males ($M = 30.74$ years old, $SD = 10.74$ years) and 184 females ($M = 32.24$ years old, $SD = 9.52$ years), who completed online questionnaires. There were no significant correlations between participants' age and research variables (math loading ratings: $r = -0.06$, $p = .30$; emotional valence ratings of math-related words: $r = -0.10$, $p = .09$; emotional valence ratings of words with negative valence: $r = 0.07$, $p = .22$; emotional valence ratings of words with neutral valence: $r = -0.08$, $p = .15$).

2.2. Measures

2.2.1. Word stimuli

To the best of our knowledge, there is no database of emotionally evocative words in Hebrew, specifically math-related words. Therefore, we created our own collection, selecting 64 Hebrew words with negative valence (e.g., "fire"), 64 Hebrew math-related words (e.g., "algebra"), and 66 Hebrew neutral words (e.g., "table") based on their length and assumed valence.

The number of letters in a word is a lexical characteristic known to be important to word recognition with the possibility of introducing confounds (Larsen et al., 2006). Thus, the three word-types were equivalent in length (math-related words: $M = 5.72$, $SD = 1.81$; negative valence words: $M = 5.66$, $SD = 1.81$; neutral words: $M = 5.67$, $SD = 1.63$; length range: 3–12 letters). There were no significant differences between word-types in word length, $F < 1$.

Information on the prevalence of Hebrew words was taken from a word corpus on the website of the National Examination and Evaluation Center in Israel (see https://hlp.nite.org.il/WebCorpora.aspx). This corpus provides an initial list of the prevalence of Hebrew words and lexemes based on 637 texts representing different genres and collected from different sources. Note that, no information was available on the prevalence of three negative words, ten mathematical words and two neutral word (see Appendix). We found a marginally significant differences between word-types in frequency, $F(2,176) = 2.90$, $p = .06$, $d = 0.44$. Post hoc comparisons using independent samples t-tests revealed a significant difference, $t(116) = -2.24$, $p < .05$, $d = 0.42$, between the frequency of the neutral ($M = 20.77$, $SD = 7.34$, frequency range 10.00–32.46) and the math-related words ($M = 17.78$, $SD = 7.02$, frequency range 10.00–34.01). There were no significant differences between the frequency of the words with negative valence ($M = 19.40$, $SD = 5.63$, frequency range 10.00–38.40) and the neutral, $t(117.71) = -1.17$, $p = .24$, and math-related words, $t(101.48) = -1.35$, $p = .17$.

2.2.2. Math loading questionnaire

The math loading questionnaire included 64 randomly sorted math-related Hebrew words. In this questionnaire, participants were asked to rate the degree to which words were related to the field of mathematics on a three-point scale (from 1 = *not a math word* to 3 = *a math word*). The coefficient alpha for the math-loading questionnaire was 0.92.

2.2.3. Emotional valence questionnaire

This questionnaire presented 194 randomly sorted Hebrew words (64 words with negative valence, 64 math-related words, and 66 neutral words). Participants were asked to rate the degree to which the words were threatening on a 5-point Likert scale (from 1 = *not threatening at all* to 5 = *very threatening*). Similar to previous research (Sylvester et al., 2016; Yee, 2017), the valence scale was adapted from the original 7 and 9-point scales (Bradley & Lang, 1999) to a 5-point scale to reduce the cognitive load that could lead to dropout. This issue is particularly important in questionnaires distributed online and not in the laboratory (Lenzner et al., 2010). The math-related words in this questionnaire were identical to those in the previous one. Using Cronbach's alpha, reliability for the emotional valence questionnaire was 0.98.

2.3. Procedure

Similar to previous studies (Roy et al., 2020; Wang et al., 2019; Zsido et al., 2018), participants were recruited through the Internet, with invitations posted on the investigators' Facebook accounts and in various Internet groups and forums. The posts described the study, invited respondents above the age of 18 years to fill in the questionnaires, and displayed a link to the questionnaires, which were created using Google Forms. The online questionnaires were open for two months, from mid-January to mid-April 2020. Participants completed basic demographic questions on age and gender. Then, they completed the math loading questionnaire and the emotional valence questionnaire.

2.4. Statistical analyses

For each participant, we calculated the average emotional valence ratings across words in each word-type (math-related words and words with negative and neutral valence) and the average math-loading rating across math-related words. Then, the emotional valence ratings were normalized to depict between-subject confidence intervals (Morey, 2008). Repeated measures analyses of variance with a Bonferroni adjustment and post hoc comparisons using paired sample t-tests looked for differences between emotional valence ratings of the three word-types (i.e., math-related words and words with negative and neutral valence). Effect sizes were tested using Cohen's d (Cohen, 1988).

Another analysis was performed on word measures across participants: for math-related words, we computed correlations between math loading ratings, emotional valence ratings, length, and frequency; and for the negative and neutral words, we computed correlations between emotional valence ratings, length, and frequency. The utility of the variables to predict the emotional valence ratings of the math-related words was examined using hierarchical linear regression, with math loading ratings, length, and frequency as the predictors. Math loading ratings were entered in the first step and word length and frequency in the following step.

The second aim was to examine gender differences in emotional valence ratings of the words. To this end, we examined the data across words. First, an independent samples t-test was used to examine gender differences in the math loading ratings of math-related words. Second, repeated measures analysis of variance with a Bonferroni adjustment and post hoc comparisons using independent sample t-tests were conducted to observe the gender effect on emotional valence ratings by the three word-types (i.e., math-related words and words with negative and neutral valence). Note that, the Bonferroni adjustment was used in order to deal with the unequal sample size between males and females (Shingala & Rajyaguru, 2015). Effect sizes were tested using Cohen's d (Cohen, 1988).

3. Results

3.1. Differences in emotional valence

Descriptive statistics of the research variables are presented in Table 1. When differences in emotional valence ratings between word-types (math-related words and words with negative and neutral valence) were examined via analyses of variance (see Fig. 1), a significant large effect of type appeared, $F(1.72,496.85) = 1503.18$, $p < .001$, *Cohen's f* = 2.27. Post hoc comparisons indicated that the words with a negative valence ($M = 3.52$, $SD = 0.51$) were rated as significantly more threatening than the math-related words ($M = 1.58$, $SD = 0.43$), $t(289) = -37.59$, $p < .001$, *Cohen's d* = 2.20. As expected, the neutral words were rated as significantly less threatening ($M = 1.26$, $SD = 0.21$) than those with a negative valence, $t(289) = 50.18$, $p < .001$, *Cohen's d* = 2.94, and the math-related words, $t(289) = 8.89$, $p < .001$, *Cohen's d* = 0.52. Additional descriptive statistics of all words are presented in Appendix.

Interestingly, there was a significant positive correlation between math loading and emotional valence ratings of the math-related words, $r = 0.66$, $p < .001$ (see Fig. 2), indicating that when the math-related word was perceived by participants to be more related to math, they rated it as more threatening. Math loading, $r = -0.53$, $p < .001$, and emotional ratings of the math-related words, $r = -0.44$, $p < .01$, were negatively correlated with their frequencies in Hebrew and positively correlated with their length; math loading: $r = 0.38$, $p < .01$; emotional valence: $r = 0.57$, $p < .001$. That is, the longer and less common the math-related word in Hebrew, the more it was rated as math-related and threatening. In contrast, emotional valence ratings of words with a negative or neutral valence did not correlate with their frequency in Hebrew, $r = 0.08$, $p = .54$, $r = -0.04$, $p = .74$, respectively, or their length, $r = -0.20$, $p = .12$, $r = 0.19$, $p = .13$, respectively.

In the next step of the analysis, a multiple linear regression model of emotional valence ratings of math-related words in which the potential predictors were math loading ratings and word length and frequency found no problems of multicollinearity among the predictors or explanatory variables based on the variance inflation factor (largest variance inflation factor = 1.42; Coakes, 2005; Hair et al., 1998). As illustrated in Fig. 3, Math loading ratings significantly explained 41% of the variance, $F(1,52) = 36.10$, $p < .001$. In the second step of regression analysis, math loading ratings, $\beta = 0.47$, $p < .001$, and word length, $\beta = 0.32$, $p < .01$, significantly explained 51% of the variance, $F(3,50) = 17.34$, $p < .001$. The contribution of word frequency to the regression model was not significant ($p = .51$).

3.2. Gender differences

3.2.1. Math-loading ratings

Gender differences in math loading ratings of math-related words were found to be non-significant, $t(288) = -1.18$, $p = .24$, *Cohen's d* = 0.15. In other words, male and female participants rated the math loading of the math-related words in the same pattern, regardless of the characteristics of the words (i.e., length or frequency).

3.2.2. Valence ratings

The main effect of gender was significant, $F(1,288) = 20.35$, $p < .001$, *Cohen's f* = 0.26, indicating that the mean gender score is significantly greater for females ($M = 2.21$, $SD = 0.03$) than for males ($M = 1.95$, $SD = 0.05$). The main effect of word-type was significant, $F(1.68,482.86) = 1417.78$, $p < .001$, *Cohen's f* = 2.22, suggesting significant differences between the word types. Specifically, it was found that the highest mean emotional valence ratings score (beyond gender) was given to the negative words ($M = 3.44$, $SD = 0.05$), followed by the mean score of the math-related words ($M = 1.54$, $SD = 0.04$), with the neutral words having the lowest mean score ($M = 1.27$, $SD = 0.02$).

Importantly, the double interaction between gender and word-type was also significant, $F(1.68,482.86) = 26.22$, $p < .001$, *Cohen's f* = 0.30, which represents a medium to large effect size (see Fig. 4). We then continued to analyze simple main effects of gender in each word-type. **In the negative words**, females' valence ratings ($M = 3.73$, $SD = 0.74$) were significantly higher than those of males ($M = 3.14$, $SD = 0.81$), $t(288) = -6.28$, $p < .001$, *Cohen's d* = 0.75. Interestingly and with high relevance to the current research questions, math-related words showed similar gender pattern as the words with negative valence. Namely, **in the math-related words**, females' valence ratings ($M = 1.67$, $SD = 0.06$) were significantly higher than those of males ($M = 1.42$, $SD = 0.07$), $t(244.26) = -2.92$, $p < .01$, *Cohen's d* = 0.34. In contrast to both negative and math-related words, **neutral words** did not show gender differences, $t(145.80) = 1.34$, $p = .18$, in the emotional ratings (for males $M = 1.29$, $SD = 0.39$; for females $M = 1.24$, $SD = 0.22$).

It should be noted that gender differences in valence ratings were significantly larger in the negative compared to the math-related words (i.e., the interaction between gender and word-type that included only negative and math-related words was significant), $F(1,288) = 10.24$, $p < .01$, *Cohen's f* = 0.18. These findings are consistent with the well-documented gender effect of negative valence words, but innovatively demonstrated that this pattern also exists in math-related words. Similarly, gender differences in valence ratings were significantly larger in the math-related compared to the neutral words (i.e., the interaction between gender and word-type that included only math-related and neutral words), $F(1,288) = 17.91$, $p < .001$, *Cohen's f* = 0.24. These findings suggest that it is not a general gender effect (i.e., the higher sensitivity of females to negative stimuli compared to males), but rather an emotional gender effect that is specific to math-related and negative stimuli. In other words, math is not perceived as information with a neutral valence.

Table 1
Descriptive statistics of research variables.

	M	*SD*	Minimum	Maximum
Math loading of math-related words	2.43	0.27	1.55	3.00
Emotional valence ratings				
1. Math-related words	1.58	0.43	0.87	2.97
2. Words with negative valence	3.52	0.51	2.15	4.51
3. Neutral words	1.26	0.36	0	2.10

4. Discussion

Experimental paradigms are often used to study the relationship between cognition, motivation, and anxiety. This study compared the emotional valence ratings of math-related words to those of negative and neutral valence words. Along with its novel findings on gender differences in the emotional perceptions of math-related verbal stimuli, the study provides researchers with an internally sound list of words that can be used to generate experimental paradigms to assess cognitive responses to math stimuli.

Three central findings emerged from the study. First, math-related words were rated as less threatening than negative valence words, but more threatening than neutral words. Second, math loading ratings were the strongest and most significant predictors of the emotional valence ratings of the math-related words. Categorization of a math-related stimulus as threatening, especially when it is perceived as more related to math, suggests that the field of numerical cognition is linked with negative affective valence. Word length also made a significant contribution to the regression model. This finding can be explained by the automatic vigilance hypothesis (Pratto & John, 1991), which assumes that the negative valence of a threatening stimulus causes a depletion of cognitive resources. In this case, when a word was more related to math and more cognitive resources were needed for word processing, the length of the word increased the threat. The processing of threatening stimuli tends to be preferred (Brosch et al., 2010; Öhman

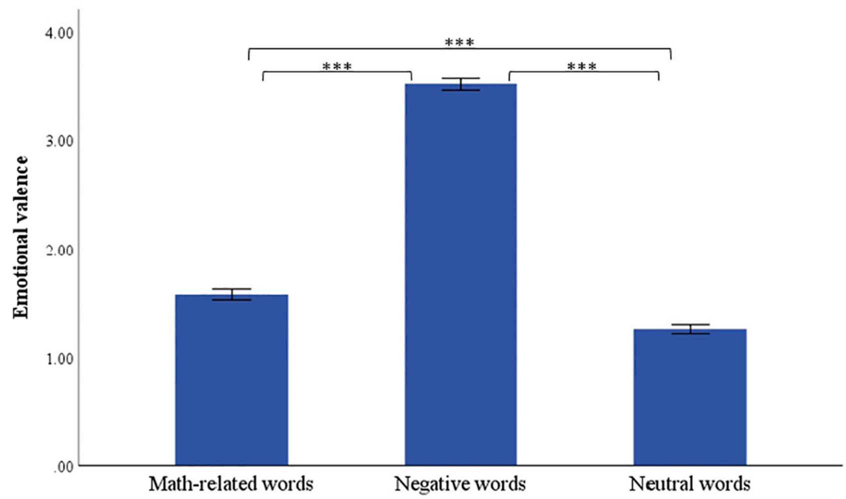

Fig. 1. Differences between word-types in emotional valence ratings.
Note. Error bars represent 95% within-subjects confidence intervals (Morey, 2008). ***$p < .001$.

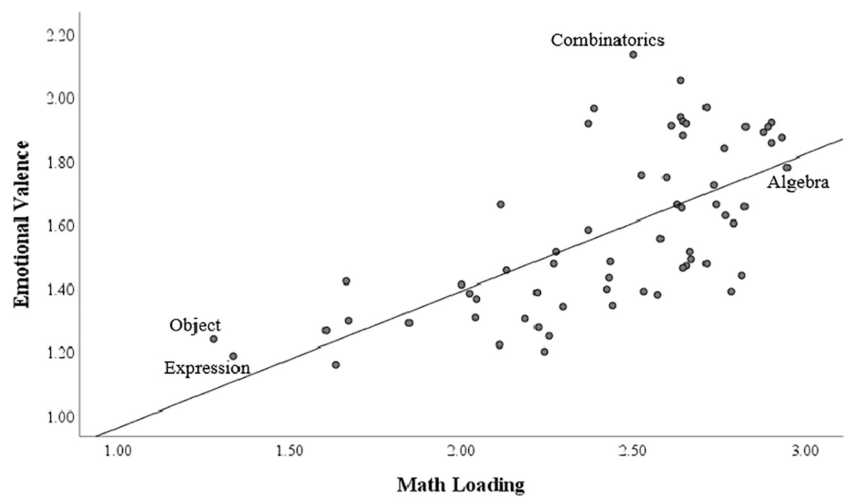

Fig. 2. Scatterplot of correlations between emotional valence and math loading ratings of math-related words.

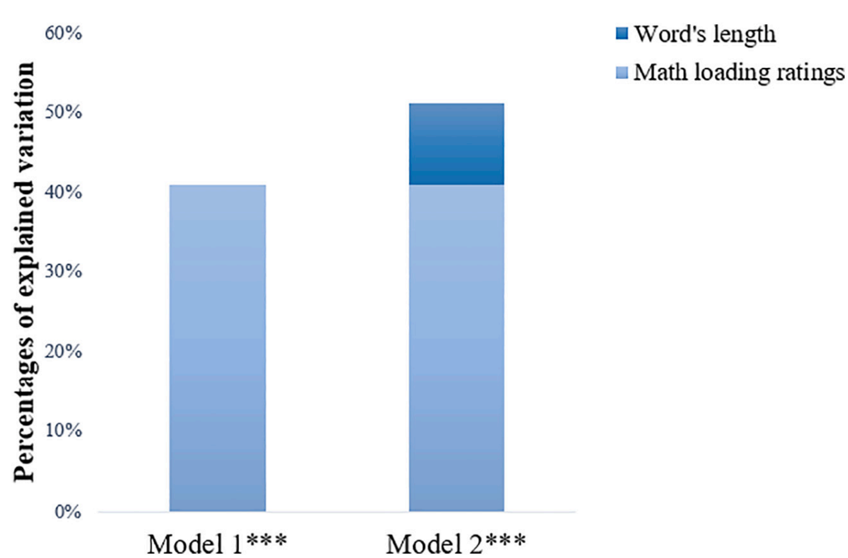

Fig. 3. Contribution of math loading ratings and word length to variance in emotional valence ratings of math-related words: hierarchical regression ($n = 54$).
Note. Math loading ratings significantly explained 41% of the variance. The contribution of word length to the regression model was 10%. ***$p < .001$.

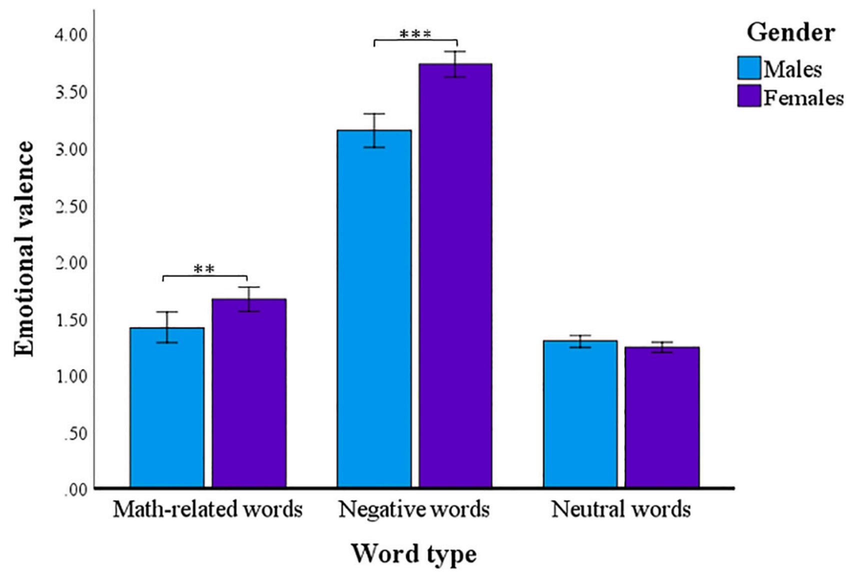

Fig. 4. Gender differences in emotional valence ratings.
Note. Error bars represent 95% within-subjects confidence intervals (Morey, 2008). $^{***}p < .001$, $^{**}p < .01$.

& Mineka, 2001; Sutton & Lutz, 2019) and to evoke high arousal (e.g., Bradley et al., 2001; MacIntyre et al., 2019). Negative valence and high arousal, in turn, are argued to be crucial to academic functioning (e.g., Mason et al., 2017; Scrimin et al., 2016; Wunsch et al., 2019).

Third, females rated negative valence words as more threatening than males. This finding is consistent with the well-documented gender effect of negative valence stimuli (Burton et al., 2005; Gohier et al., 2013; Schienle et al., 2005), indicating a unique gender differences when it comes to perception of negative information in the world. Innovatively, the current findings demonstrated that this pattern is also exists in math-related words, with females rated these words, but not the neutral words, as more threatening than males. Importantly and in line with previous work indicating females are more emotionally reactive to numerical information (e.g., Devine et al., 2018; Hill et al., 2016), gender differences in valence ratings of math-related and neutral words were significant. Therefore, the current findings revealed an emotional effect that is specific to math-related stimuli that cannot be explained by a general gender effect. That is, math-related information is linked with a negative affective valence, especially among females.

Gender differences in the perceived emotional valence of math-related information may explain the well-documented gender differences in perceptions of math ability (e.g., Reilly et al., 2019; Seo et al., 2019; Wang & Degol, 2017) and math affectivity and attitudes (e.g., Devine et al., 2018; Else-Quest et al., 2010; Hembree, 1990). These gender differences ultimately lead to lower percentages of women in STEM career (Wang & Degol, 2017; Watt et al., 2017). In future studies, it would be interesting to test whether these correlations hold among those in the profession. Is there a relationship between the type of occupation (STEM\non-STEM) and the emotional valence ratings of math-related words?

In the anxiety-cognition paradigm (e.g., Abado et al., 2020) or the motivation-cognition experimental paradigm (e.g., Vogt et al., 2020), the selection of emotionally evocative words (Weierich et al., 2008) is an important variable in the examination of the relationship between the processing of information with negative valence and cognitive processes. For instance, to explore information processing abnormalities in math anxiety disorders, math-related words are usually presented with neutral words (e.g., Rubinsten et al., 2015; Suárez-Pellicioni et al., 2015). This study facilitated this type of examination by collecting emotional rating data on a pre-selected group of 194 neutral, emotional- and math-related words (see Appendix). To the best of our knowledge, this is a pioneering database of emotional words in the field of numerical cognition.

The findings strongly suggest the need for further research in the area. First, it is important to investigate when and why math-related information begins to pose a threat. Deficits in functioning in math-related situations, either academic or in daily life, accompanying the negative perception of math-related information may create a vicious cycle: avoidance of math-related threatening stimuli will create gaps in learning, which, in turn, will exacerbate emotional problems (Krinzinger et al., 2009). Second, to trigger the interest and success of females in math-related careers, researchers need to explore why they tend to perceive math-related stimuli as more threatening than males, when these gender differences begin to appear, and how they can be reduced.

From a practical perspective, there is a need to develop innovative evidence-based curricula aimed at presenting the math field in a more intriguing, challenging, and positive way. These programs should target early childhood education, as feelings of tension, anxiety, and fear when engaging in math have been found as early as the first grade (Maloney et al., 2015) and may increase over time (Hembree, 1990). Appropriate curricula may help to reduce gender differences in perceptions of math ability (e.g., Reilly et al., 2019; Seo et al., 2019; Wang & Degol, 2017) and attitudes to math (e.g., Devine et al., 2018; Else-Quest et al., 2010; Hembree, 1990). Similarly, parents and educators need to change children's perception of math and introduce this field as more positive and interesting. For example, parents' math anxiety and parenting with more controlling aspects have been related to higher levels of math anxiety, poorer arithmetic skills, and less intrinsic math motivation and school learning motivation (Daches Cohen & Rubinsten, 2017; Maloney et al., 2015). By the same token, increased engagement in academic behaviors and decreased avoidance behaviors have been found in the classrooms of teachers who encourage students cognitively as learners and motivationally by including a supportive atmosphere, humor, and personal attention (Turner et al., 2002).

4.1. Limitations

Although this study makes a novel contribution to the existing literature, there are several limitations. First, recruiting participants via Internet and social networks may threaten the findings' reliability and validity (e.g., Gosling et al., 2004). In many studies, however, Internet-based data have had high reliability, valid replicability, and theoretical consistency compared to data gathered in a traditional lab setting (e.g., Germine et al., 2012; Nosek et al., 2002). In this study, the coefficient alphas for the math-loading and emotional valence questionnaires were 0.92 and 0.98, respectively. Second, norms of the emotional perception of verbal information can vary across cultures and languages, and this study used only one culture/language. There is a need to investigate gender differences in emotional perceptions of math-related words in other languages and cultures.

4.2. Conclusion

The study illustrates that math-related words, and arguably the field of mathematics more generally, are associated with a negative emotional valence, but more so in females than males. The findings should attract the attention of policy makers and educators seeking to increase the prevalence of women in STEM careers, especially considering the important role of math proficiency in personal and economic success.

Declaration of competing interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be interpreted as a potential conflict of interest.

Appendix A

Table 3
Descriptive statistics of the math-related words.

Words	English translations	Words' frequencies in Hebrew	Math loading ratings		Emotional ratings	
			M	SD	M	SD
גאומטריה	Geometry	10	2.81	0.48	1.89	1.31
מתמטיקה	Mathematics	17.78	2.96	0.24	2.28	1.41
אלגברה	Algebra	10	2.95	0.26	1.94	1.27
משוואה	Equation	13.01	2.82	0.43	1.85	1.17
אלגוריתם	Algorithm	10	2.70	0.58	2.38	1.45
פונקציה	Function	14.77	2.72	0.57	1.95	1.23
ביטוי	Expression	28.81	1.37	0.63	1.24	0.62
סימטריה	Symmetry	14.77	2.06	0.77	1.62	1.11
חזקה	Power	27.24	2.81	0.48	1.97	1.32
שברים	Fractions	13.01	2.78	0.46	2.23	1.37
סדרות	Series	20.79	2.18	0.77	1.59	1.02
הסתברות	Probability	14.77	2.68	0.53	2.01	1.28
התפלגות	Distribution	16.02	2.63	0.60	1.97	1.23
תיכון	Median	23.22	1.74	0.74	1.54	0.96
רדיוס	Radius	10	2.72	0.51	1.62	1.00
קוטר	Diameter	13.01	2.69	0.48	1.75	1.21
מצולעים	Polygons	13.01	2.69	0.54	1.66	1.07
סינוס	Sine		2.82	0.46	2.09	1.40
קוסינוס	Cosine		2.93	0.29	2.17	1.50
טנגנס	Tangent		2.83	0.47	2.14	1.48
שורש	Square root	23.42	2.40	0.74	1.74	1.07
טריגונומטריה	Trigonometry		2.89	0.37	2.15	1.44
טרינום	Trinomial		2.66	0.65	2.33	1.51
פולינום	Polynomial		2.56	0.73	2.22	1.48
מינוס	Minus	16.02	2.40	0.69	2.10	1.45
פלוס	Plus	23.01	2.14	0.76	1.33	0.82
חילוק	Division	10	2.74	0.48	1.67	1.13
חיבור	Addition	22.79	2.28	0.68	1.41	0.94
חיסור	Subtraction		2.57	0.65	1.56	1.02
כפל	Multiplication	10	2.80	0.45	1.62	1.13
מעריך	Exponent	24.47	1.95	0.83	1.49	0.91
חישוב	Calculation	19.54	2.67	0.58	1.60	1.01
פרבולה	Parabola		2.92	0.37	2.24	1.48
משיק	Tangent	10	2.50	0.67	1.71	1.19
צורה	Shape	27.08	1.69	0.73	1.24	0.66
גוף	Object	30.53	1.31	0.54	1.35	0.78
היקף	Perimeter	23.22	2.32	0.69	1.53	0.93
שטח	Area	27.85	2.07	0.74	1.48	0.89
נפח	Volume		1.48	0.89	2.27	0.74
וקטור	Vector	10	2.61	0.68	2.18	1.39
קומבינטוריקה	Combinatorics		2.46	0.78	2.49	1.62
ליניארי	Linear	10	2.73	0.55	1.97	1.37
מכפלה	Product	16.02	2.86	0.42	1.68	1.08
מרחב	Space	25.44	1.78	0.76	1.38	0.83
מספרים	Numbers	27.71	2.47	0.69	1.48	0.90
נוסחאות	Formulas	14.77	2.77	0.47	2.02	1.29
נעלמים	Unknowns	22.04	2.57	0.62	2.39	1.40
אומדן	Estimation	14.77	2.16	0.73	1.65	1.09
סוגריים	Parentheses	10	1.82	0.82	1.42	0.92
חשבון	Arithmetic	27.48	2.56	0.65	1.87	1.25
אחוזים	Percentages	27.56	2.70	0.46	1.92	1.26
מאיות	Hundredths	10	2.50	0.67	1.48	0.92
עשיריות	Tenths	10	2.60	0.62	1.59	1.06

(continued on next page)

Table 3 (*continued*)

Words	English translations	Words' frequencies in Hebrew	Math loading ratings		Emotional ratings	
			M	SD	M	SD
אלפים	Thousands	26.13	2.29	0.75	1.50	0.97
מיליארד	Billion	27.08	2.34	0.72	1.44	0.96
אריתמטיקה	Arithmetic	10	2.72	0.60	2.16	1.49
מיליון	Million	34.01	2.15	0.78	1.35	0.86
אינטגרל	Integral	13.01	2.90	0.36	2.16	1.49
גרף	Graph	13.01	2.49	0.64	1.59	0.96
טבלה	Table	13.01	1.59	0.67	1.29	0.71
סטטיסטיקה	Statistics	16.99	2.69	0.56	2.26	1.50
מחוגה	Calipers	16.02	2.34	0.77	1.39	0.78
מנסרה	Prism	16.99	2.21	0.84	1.90	1.24
גימטריה	Gematria	10	2.47	0.76	1.69	1.14

Table 4
Descriptive statistics of the negative words.

Words	English translations	Words' frequencies in Hebrew	Emotional ratings	
			M	SD
התחשמלות	Electrocution	13.01	4.12	1.19
התרסקות	Crash	13.01	4.32	1.02
אלימות	Violence	24.31	4.01	1.12
צונאמי	Tsunami	20.79	4.17	1.13
התדרדרות	Deterioration	14.77	3.40	1.31
צמרמורת	Shiver	19.54	2.42	1.31
תסכול	Frustration	18.45	3.16	1.37
פסיכופט	Psychopath	13.01	3.91	1.36
אסיר	Prisoner	21.76	3.28	1.32
מפחיד	Frightening	23.98	3.40	1.43
התעללות	Abusing	17.78	4.27	1.03
חיסונים	Vaccines	16.99	2.27	1.31
תאונה	Accident	21.46	4.16	1.09
שיתוק	Paralysis	17.78	4.23	1.16
פושע	Criminal	21.14	3.54	1.27
התאבדות	Suicide	23.22	4.33	1.02
אכזבה	Disappointment	22.30	3.19	1.27
גירושין	Divorce	16.99	3.76	1.15
מוות	Death	28.20	4.32	1.13
אנדוקרינולוג	Endocrinologist		2.64	1.52
כישלון	Failure	14.77	3.60	1.16
אומללות	Wretchedness	13.01	3.70	1.17
גניבה	Theft	13.01	3.42	1.31
מכות	Blows	25.68	3.75	1.19
בגידה	Betrayal	19.54	3.90	1.20
אבדון	Destruction	10.00	3.78	1.33
מפולת	Slides	14.77	3.52	1.38
כלא	Jail	24.77	3.84	1.30
מלחמה	War	32.46	4.26	1.07
דקירה	Stabbing	10.00	4.21	1.04
דיכאון	Depression	10.00	3.99	1.18
טרור	Terror	28.13	4.46	0.91
משבר	Crisis	25.19	3.38	1.19
חרם	Excommunication	20.00	3.74	1.30
טעות	Mistake	27.24	2.42	1.19
הרס	Ruination	25.44	3.75	1.26
לחץ	Pressure	32.23	3.28	1.32
שגיאה	Error	20.00	2.37	1.19
קולונוסקופיה	Colonoscopy		3.52	1.28
גיהנום	Hell	18.45	3.58	1.51
פריצה	Break-in	13.01	3.63	1.36
מעצר	Arrest	21.76	3.56	1.31
אונס	Rape	21.46	4.59	0.85
הלוויה	Funeral	19.03	3.73	1.31
פיגועים	Attacks	19.54	4.53	0.87
שונאים	Haters	20.00	3.26	1.39
טילים	Missiles	27.78	4.18	1.09
הזדקנות	Aging	16.02	3.47	1.25
חששות	Concerns	18.45	2.99	1.29
הרוגים	Dead	25.80	4.39	0.94
טביעה	Drowning	13.01	4.26	1.22
אובדנות	Suicidality	10.00	4.14	1.12
אזעקה	Siren	17.78	3.68	1.30

(*continued on next page*)

Table 4 (*continued*)

Words	English translations	Words' frequencies in Hebrew	Emotional ratings	
			M	SD
פיטורין	Dismissal	16.02	3.66	1.25
ביקורתיות	Criticism	10.00	2.52	1.28
שריפה	Fire	21.14	4.18	1.02
כרישים	Sharks	14.77	3.54	1.32
משרפות	Crematoriums		4.40	1.02
רצח	Murder	28.81	4.44	1.02
מחבל	Terrorist	17.78	4.49	0.90
אנטישמיות	Antisemitism	14.77	4.16	1.01
צרחות	Screams	16.99	3.38	1.20
כאבים	Pains	22.55	3.62	1.23
קטיושות	Katyushas	23.80	4.07	1.19

Table 5
Descriptive statistics of the neutral words.

Words	English translations	Words' frequencies in Hebrew	Emotional ratings	
			M	SD
היסטוריה	History	26.43	1.57	1.00
ארטישוק	Artichoke	10.00	1.16	0.63
אמבטיה	Bathroom	19.54	1.09	0.38
כפתור	Button	20.79	1.13	0.54
מיקרופון	Microphone	10.00	1.28	0.75
אפרסמון	Persimmon		1.10	0.44
שולחן	Table	30.29	1.12	0.59
באולינג	Bowling	10.00	1.10	0.42
כדור	Ball	33.28	1.30	0.74
פרחים	Flowers	28.57	1.02	0.17
ירקות	Vegetables	25.19	1.06	1.06
המשכיות	Continuity	14.77	1.50	1.01
מבוגרים	Adults	26.72	1.63	1.08
פירות	Fruits	26.63	1.06	0.32
עבודה	Work	33.67	1.67	0.88
מקרר	Refrigerator	17.78	1.13	0.51
שירותים	Services	22.04	1.25	0.64
צבעים	Colors	26.43	1.14	0.53
מולקולה	Molecule	16.99	1.79	1.18
עמילן	Starch	10.00	1.28	0.66
נייר	Paper	29.82	1.06	0.29
אנציקלופדיה	Encyclopedia	14.77	1.29	0.79
גנטיקה	Genetics	13.01	1.81	1.04
מונולוג	Monologue	16.02	1.42	0.87
וטרינר	Veterinarian	10.00	1.42	0.86
סימן	Sign	30.29	1.36	0.80
כלבים	Dogs	27.08	1.53	0.86
ברקוד	Barcode		1.21	0.62
כרטיס	Card	26.72	1.12	0.50
זמן	Time	38.40	1.86	1.24
חולצה	Shirt	22.55	1.11	0.53
מקהלה	Choir	19.03	1.19	0.64
הורמון	Hormone	22.04	1.69	1.01
צעיף	Scarf	14.77	1.13	0.56
מחשב	Computer	27.32	1.30	0.68
קיר	Wall	26.33	1.20	0.66
סבתא	Grandmother	31.04	1.04	0.25
תיק	Bag	26.33	1.13	0.56
דלת	Door	31.46	1.12	0.43
רמקול	Speaker	13.01	1.17	0.53
אנתרופולוגיה	Anthropology	10.00	1.69	1.10
טקטיקה	Tactics	18.45	1.62	0.96
הופעה	Appearance	22.30	1.21	0.48
משחק	Play	30.49	1.13	0.40
ארון	Closet	25.68	1.26	0.76
מזוודה	Suitcase	17.78	1.07	0.33
מיומנות	Proficiency	20.79	1.35	0.72
נעליים	Shoes	26.23	1.12	0.43
מסטיק	Bubble gum	16.02	1.10	0.52
פעלולים	Stunts	10.00	1.81	1.06
מגירה	Drawer	13.01	1.11	0.43
טלויזיה	Television	28.45	1.18	0.50
מקלחת	Shower	16.02	1.10	0.39

(*continued on next page*)

Table 5 (*continued*)

Words	English translations	Words' frequencies in Hebrew	Emotional ratings	
			M	SD
תקליטור	Compact disc	13.01	1.15	0.59
תמונה	Image	27.85	1.14	0.53
אוקינוס	Ocean	17.78	1.91	1.20
ארכיאולוג	Archaeologist	16.99	1.24	0.63
מחברת	Notebook	23.98	1.06	0.32
קומדיה	Comedy	13.01	1.10	0.42
קרמיקה	Ceramics	17.78	1.20	0.60
יוד	Iodine	13.01	1.52	0.93
צלחת	Plate	22.30	1.09	0.43
אסטרונאוט	Astronaut	13.01	1.47	0.95
פולחן	Cult	20.00	2.66	1.36
עטיפה	Cover	13.01	1.11	0.47
רפרטואר	Repertoire	13.01	1.54	1.04

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