MIND, BRAIN, AND EDUCATION

Individual Differences in Emotional Reactivity and Academic Achievement: A Psychophysiological Study

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ABSTRACT— Factors related to grade point average (GPA) are of great importance for students' success. Yet, little is known about the impact of individual differences in emotional reactivity on students' academic performance. We aimed to examine the emotional reactivity–GPA link and to assess whether self-esteem and psychological distress moderate this relationship.

Eighty undergraduate students reported on their GPA, self-esteem, and psychological distress. Students' pupil radius was monitored during affective picture viewing to assess sympathetic activation in response to emotional stimuli. Cluster analysis on pupil reactivity to pictures identified low, average, and high emotionally reactive students. Regression analyses indicated that profiles of emotional reactivity were associated with GPA. This relationship was moderated by self-esteem, but not psychological distress. Among students with higher emotional reactivity, those with lower self-esteem reported poorer GPA. Findings document the importance of differences in students' emotional reactivity and self-esteem in relation to academic success.

Success in college is strongly associated with positive financial and career outcomes (Plant, Ericsson, Hill, & Asberg, 2005); moreover, it is a key criterion for postgraduate selection and graduate employment and is predictive of occupational status (Strenze, 2007). Undergraduate university students' performance is usually expressed in terms of grade point average (GPA), that is, the mean of marks from courses contributing to assessment of the final degree. GPA is considered an objective measure of academic functioning and achievement with good internal reliability and temporal stability (e.g., Kobrin, Patterson, Barbuti, Mattern, & Shaw, 2008).

Given the short- and long-term importance of GPA in the life of a student, it is a priority to understand the factors that may influence academic performance. Research for decades has highlighted the connection between learning and cognitive or motivational aspects (e.g., Ainley, 2006). Yet, a common experience in the life of students is the feeling that their emotionality may influence their academic performance, affecting their ability to process and comprehend especially during the exams. Therefore, it is important to know more about the role of emotional factors in students' academic success.

In this regard, it should be pointed out that research on achievement emotions and students' performance has been flourishing in recent years (Linnenbrink-Garcia & Pekrun, 2011; Pekrun & Linnenbrink-Garcia, 2014). For a long time educational research has mainly focused on test anxiety and hundreds of studies have indicated its role in students' academic achievement (e.g., Stober & Pekrun, 2004; Zeidner, 2007). Only relatively recently have individual differences in other achievement emotions, such as enjoyment (e.g., Frenzel, Goetz, Lüdtke, Pekrun, & Sutton, 2009) and boredom (e.g., Daniels, Tze, & Goetz, 2015) been investigated. Specifically, the link between emotions and academic achievement has been addressed in terms of how and why student's emotions emerge, the role of emotions in shaping students' engagement, and the use of emotional regulation for supporting academic performance (e.g., Ainley, Hidi, & Berndorff, 2002; Nett, Goetz, & Hall, 2011; Pekrun & Stephens, 2009; Valiente, Lemery-Chalfant, & Swanson, 2010). Research has gained knowledge about antecedents

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and consequences of emotions in relation to specific domains or disciplines (Dettmers et al., 2011), as well as about the relations between emotions and motivational constructs, such as self-concept (Goetz et al., 2012).

However, what is still very sparse is research on individual differences in students' emotional arousal (measured in terms of students' physiological activation) at a more general level, that is, their autonomic activation in response to everyday emotional material (i.e., not specifically related to the academic context). Students who are in general more disposed to high emotional reactivity may engage and perform differently from their peers who are less emotionally reactive to environmental stimuli.

To extend current research the present study aims to gain knowledge on the link between academic performance and dispositional emotionality, which is defined as an individual difference in the tendency to respond with different intensity to emotional material (Eisenberg, Fabes, Guthrie, & Reiser, 2000).

Previous research reports a negative association between negative affective states and academic outcomes, probably explained by a resource allocation model in which high negative emotionality interferes with students' cognitive processes and lowers performance by drawing their attention away from the task (Brand, Reimer, & Opwis, 2007; Pekrun, Elliot, & Maier, 2009).

On the other hand, empirical findings show that positive emotions enhance students' functioning by promoting creative thinking and engagement (Valiente, Swanson, & Eisenberg, 2012), and by contributing to students' interest and effort (Pekrun et al., 2009). Yet, high arousal positive emotions (e.g., exuberance, excitedness, and elatedness) may detract from achievement, working as possible distractors (Valiente et al., 2012).

These data are strictly linked to emotions (either positive or negative) experienced in the academic environment or in relation to learning materials. However, the general predisposition of a student to be more or less physiologically reactive to an everyday emotional stimulus (pleasant, unpleasant, or neutral), which is not directly linked with the academic or learning environment, may also be related to his/her average academic performance. Developing a better understanding of this relation will shed some further light on the ways in which individual differences in experiencing emotions is directly associated with GPA.

Specific traits which mark each individual on his/her response to emotional stimuli may partially explain the different, and sometimes conflicting, findings in educational studies linking emotions and achievement (Seery, Weisbuch, Hetenyi, & Blascovich, 2010; Valiente et al., 2012), yet this issue has still received little attention.

Emotional reactivity refers to characteristics of the emotional response, including the threshold of stimuli needed to generate an emotional response and the intensity of emotional response once emotion is generated (Davidson, 1998). Some students clearly experience particular emotions more intensely than others, and also react more strongly to arousing (positive or negative) stimuli. The study of these individual differences may elucidate the role of emotionality within the academic context. That is, students' autonomic reaction when processing emotionally engaging visual stimuli, which are known to cause emotional arousal, may be associated with the way they perform in their undergraduate courses.

When studying physiological responses to emotional stimuli, two dimensions of affect variation have been identified: valence and arousal (Bradley & Lang, 2000). Valence refers to the degree of pleasantness associated with emotion, either high (pleasant emotion) or low (unpleasant emotion) (Lang, 2010). Arousal is proposed to be orthogonal to valence and refers to the intensity of the emotional activation, ranging from excited to calm. Previous research indicates that individuals respond differently to stimuli depending on the stimuli hedonic valence, and a different neural response is also associated with pleasant and unpleasant material (Lane, Reiman, Ahern, Schwartz, & Davidson, 1997; Morris et al., 1996). Moreover, many studies have shown that positive and negative affect differently impact on cognitive performance, such as memory, executive functioning, and academic outcomes (Burbridge, Larsen, & Barch, 2005; Nadler, Rabi, & Minda, 2010). In relation to arousal, it has been found that it can exacerbate the effects of valence when stimuli are very arousing as well as unpleasant (Watters, Martin, & Schreter, 1997), yet the same is not always true when responding to pleasant stimuli (Sallquist et al., 2009).

Overall, the relationship between arousal and cognition has long been documented by the Yerkes and Dodson (1908) principle, that is, an optimal performance in any task is contingent on an optimal arousal level. Either over-arousal or under-arousal may lead to performance deficits in an U-inverted fashion, where performance varies as a function of level of arousal (Harrison, 2015). In recent years, the U-inverted relationship between arousal and performance has been supported by neuroscience studies in which cerebral cortex activity is shown to be modulated by neurotransmitter systems that are differently affected by behavioral state conditions related to mood, stress, attention, and arousal (Critchley & Harrison, 2013). Furthermore, an individual characterized by a general tendency to be highly activated in response to a large number of environmental stimuli, both negative and positive, can be more easily hyper-aroused and hence be more prone to perform poorly (Harrison, 2015).

Although emotional reactivity can be assessed with self-report measures, doing so presents disadvantages because individuals may not be able to reflect accurately on their emotional response to differently arousing stimuli (Nisbett & Wilson, 1977). Because psychophysiological measures do not rely on participants' conscious attention, these measures can avoid such limitations. One way of assessing emotional arousal and sympathetic activation in response to the presentation of affective material is the measure of pupil diameter changes (Bradley, Miccoli, Escrig, & Lang, 2008; Laukka, Haapala, Lehtihalmes, Väyrynen, & Seppänen, 2013). In general, pupil size variation as a physiological process has been connected to behavioral and emotional responses. Evidence suggests that pupils dilate more in pleasant and unpleasant pictures than in neutral pictures during picture viewing, thus concluding that pupil dilatation is determined by emotional arousal despite hedonic valence (Bradley et al., 2008; Laukka et al., 2013). Yet, previously conducted studies have also found a bidirectional effect of emotion on pupillary change, reporting that pupil constricted when people viewed unpleasant stimuli and dilated when viewing pleasant pictures (Hess & Polt, 1960). Changes in pupil diameter are controlled by two muscles (i.e., the dilator and the sphincter) that are differentially influenced by activity in the sympathetic and parasympathetic branches of the nervous system. Elevated sympathetic activity increases the activity of the dilator muscle, prompting dilation, whereas inhibition of parasympathetic activity lessens constriction of the sphincter-muscle, which also results in dilation (Steinhauer, Siegle, Condray, & Pless, 2004). Furthermore, Bradley et al. (2008) have found close covariation of pupil dilation with skin conductance (which increases in response to high emotional arousal compared with low arousal; see, e.g., Lang, Greenwald, Bradley, & Hamm, 1993), thus suggesting that pupil change in response to emotional material is mediated by a direct sympathetic innervation of the dilator muscle. Hence, pupil change can be a reliable measure of individual differences in emotional arousal and autonomic activation.

Individuals who show the largest emotional reactivity in response to viewing emotionally arousing stimuli may also have lower GPA and a harder time in their college career (Docherty, Rhinewine, Nienow, & Cohen, 2001). However, other factors may play a significant role in this association (e.g., Valiente et al., 2012). There are a number of well-known psychological correlates of students' academic performance (see Richardson, Abraham, & Bond, 2012 for a review), among which some have been shown to work as protective factors while others constitute risk factors for low academic performance or even school drop-out.

In the present study, we considered students' general self-esteem as a possible moderator, working as a protective factor in the link between emotional reactivity and GPA. It is worth underlining that we have taken into account this general factor instead of the more specific academic self-concept because our aim was to investigate students' physiological reactivity in response to everyday emotional material, which is a general disposition emotionality not related to the academic context.

Previous studies have found that self-esteem is associated both with emotional states (Sowislo & Orth, 2013) and academic functioning (Zeigler-Hill et al., 2013). A large body of evidence is broadly consistent with the idea that self-esteem serves a negative emotionality-buffering function (see Solomon, Greenberg, & Pyszczynski, 1991 for a review). Self-esteem is negatively correlated with negative emotionality and positively correlated with successful coping with stress and with indicators of high positive affect (Orth, Robins, & Widaman, 2012). Moreover, empirical results concerning the link between general self-esteem and academic outcomes have indicated that there is a positive association between the two variables, even if in some cases the strength of this association has been modest (see Baumeister, Campbell, Krueger, & Vohs, 2003 for a review). Hence, high levels of self-esteem may offer protection against the consequences of negative emotional states and high arousal on students' academic performance.

In terms of risk factors, abundant evidence has been generated on the co-occurrence of risk across psychological and academic domains, as students with psychological distress tend to simultaneously show problems in academic performance (Valdez, Lambert, & Ialongo, 2011). For example, students with clinical levels of internalizing problems in school are more likely to perform poorly and even drop their academic career (Duchesne, Vitaro, Larose, & Tremblay, 2008). A general negative mood and depression are associated with a reduction in cognitive functioning, which may be explained by a reduction of information processing capacity (Ellis & Ashbrook, 1988). Moreover, it has been proposed that psychological distress moderates the relation between social and emotional maladjustment and academic failure (Wentzel, 1998; Wentzel & Caldwell, 1997). From a different perspective, well-known patterns exist among clinical populations. For example, emotional hyper-reactivity to visual stimuli has been found to be associated with anxiety symptoms and poor academic performance (Goldin, Manber, Hakimi, Canli, & Gross, 2009). In addition, students with emotional hyper-reactivity who experience more test anxiety have a lower college performance compared to students experiencing less distress (Nelson, Lindstrom, & Foels, 2015). We therefore sought to examine psychological distress as a potential risk factor in the link between individual differences in emotional reactivity and students' GPA.

The main purpose of this study was to investigate the link between individual differences in emotional reactivity and academic achievement by assessing whether changes in pupillary responses to emotional stimuli are related to GPA. Furthermore, we aimed to evaluate whether this association, if present, was moderated by students' levels of self-esteem and psychological distress. Given that female gender has been found to be associated with low self-esteem (Diseth, Meland, & Breidablik, 2014), elevated psychological distress (Rosenfield & Mouzon, 2013), and high emotional reactivity (Bradley, Codispoti, Sabatinelli, & Lang, 2001), gender was controlled in the analyses.

We asked students to report their GPA and assessed their self-reported self-esteem and psychological distress. In addition, a passive picture-viewing task involving the presentation of standardized emotional stimuli taken from the International Affective Picture System (IAPS; Lang, Bradley, & Cuthbert, 2008) was employed as a direct measure of students' emotional reactivity. The picture-viewing methodology has been widely used in emotion research with adults. Emotional reactivity was measured by monitoring pupillary changes in students' response to a standardized set of pleasant, unpleasant, and neutral pictures (Bradley et al., 2008). Pupil diameter is a direct and reliable index of sympathetic nervous system activation that covaries with emotional arousal, with diameter being larger for both pleasant and unpleasant compared to neutral stimuli (Bradley et al., 2008).

Based on the scant literature on this topic, we hypothesized that students who were more reactive to emotional material (independently from hedonic valence) would have lower GPA. In addition, we assessed the role of self-esteem and psychological distress in this relationship. Specifically, we expected self-esteem to moderate the emotional reactivity–GPA link. Specifically, among students with higher emotional reactivity those with elevated self-esteem would perform better than those with low self-esteem (protective factor). Furthermore, we expected both a main and an interactive effect of psychological distress on GPA. Specifically, we expected students with high levels of psychological distress to have lower GPA than those reporting low levels of psychological distress (risk factor), and that this effect would be stronger in students with higher emotional reactivity.

METHOD

Participants

Participants were 80 (21 male) undergraduate students of psychology ($M_{age} = 21.79$, $SD = 2.05$) from a large public university in northern Italy, who received course credit for their participation. All students had normal or corrected-to-normal vision, and their native language was Italian. Most students were from middle-class families, and 70% reported being in the average population regarding their socioeconomic status (on a 3-point scale: *low, average,* and *high* SES). The validity of pupil change data for 13 of these students was very poor (i.e., the eyes could be found by the eye tracker for less than 70% of the images presentation); in addition, two students had incomplete data on questionnaires. Hence, 65 students (female 46, 71%) were considered in the statistical analyses. The University Ethical Committee reviewed and approved the study protocol, and voluntary written consent was obtained from all participants.

Measures

Grade Point Average

The measure of academic achievement was students' self-reported cumulative GPA over their college experience to date. All students were at their second year of the undergraduate program and had completed between 8 and 10 exams.

General Self-Esteem

Students' self-esteem was assessed with the general positive self-image subscale of the Self-Description Questionnaire-I (Marsh, 1988), which has been validated for the Italian population by Camodeca, Di Michele, Mela, and Cioffi (2010). In this 10-item subscale, students are asked to respond to statements such as, "I like how I am" and "When I do something I can do it well," with response options ranging from 0 = *not at all* to 4 = *very much*. In this study, Cronbach's alpha for the general positive self-image scale was .90.

Psychological Distress

The Kessler psychological distress scale is a 10-item global measure of psychological distress based on questions about the level of anxiety and depressive symptoms experienced in the most recent 4-week period. Example of items are "In the last 4 weeks how often did you feel like you were going to have a nervous breakdown?" or "In the last 4 weeks how often did you feel depressed?" Scores range from 10 to 50, with a higher score indicating greater psychological distress. It is known for its brevity, strong psychometric properties (Kessler et al., 2002), and the ability to differentiate between cases and noncases of psychological distress. The K-10 has been used in government health surveys in the United States and Canada, as well as by the World Health Organization. The reliability of the scale, which included both anxiety and depression items, was .84.

Materials and Design

Stimuli were 96 pictures selected from the International Affective Picture System (IAPS; Lang et al., 2008), consisting of 32 pleasant (mean pleasure/arousal = 7.0 and 5.5), 32 neutral (mean pleasure/arousal = 4.9 and 3.4), and 32 unpleasant (mean pleasure/ arousal = 2.4 and 5.9) pictures (the same stimuli used by Bradley et al., 2008). Rated arousal was equivalent for pleasant and unpleasant stimuli. All pictures portrayed people who were balanced for stimulus complexity, were landscape (1,024 × 768) in orientation, and were displayed in 16-bit grayscale. Using Adobe Photoshop (version 7.01; Adobe Systems Inc., San Jose, CA), the mean luminosity of the selected pictures was modified such that the mean and distribution of luminosity values for each of the picture sets (pleasant, neutral, and unpleasant) did not differ. Pictures were displayed for 6 s each, with an intertrial interval of 10 s. A grayscale image with mean luminosity computed across all pictures was displayed during the 10-s interval to control the level of illumination prior to picture onset. Pictures were arranged in blocks of six, with two pictures of each hedonic content (pleasant, neutral, and unpleasant) in each block; pictures of different valence were randomized within blocks. Pictures were viewed in one of two different orders across participants, with a specific picture viewed in either the first half or the second half of the study, across orders.

Eye-Tracking Apparatus

Picture presentation was controlled by Tobii-Studio (1.7) software, which also recorded the data. Pupil radius was recorded using the Tobii T120 eye-tracker, manufactured by Tobii Technology (Stockholm, Sweden). The Tobii T120 is integrated into a 17-inch TFT monitor with a maximum resolution of 1,280 × 1,024 pixels. The monitor was located in the lab, at a distance of 100 cm from where the participant was seated. The eye-tracker embeds five near-infrared light emitting diodes and a high-resolution camera with a charge coupled device sensor. The camera samples pupil location and pupil size at the rate of 120 Hz. Pupil radius was sampled for 2 s prior to picture onset, for 6 s during picture onset, and 3 s following picture offset.

Procedure

Participants were invited to a department lab equipped with the Tobii T120 eye-tracker. Upon arrival at the lab, each participant signed a consent form and was seated in a comfortable chair in front of the monitor in a dimly lit room. Each participant was instructed that a series of pictures would be displayed, and that each picture should be viewed the entire time it was on the screen. Following three practice trials, the set of 96 pictures was presented. After the viewing, students were asked to complete a short questionnaire assessing socio-demographic information, general self-esteem, and psychological distress. In addition, they were asked to report their cumulative GPA up to that point. Before leaving the lab, participants were debriefed and thanked for their participation.

Data Reduction

Samples where the pupil was obscured due to blinking were identified, and linear interpolation was used to estimate pupil size. Based on the average waveform during picture viewing (see Figure 1a), the initial light reflex during picture viewing was scored as the maximum extent of pupil constriction in a window from 0 to 1,000 ms after picture onset. The emotional reactivity to each picture for each participant was calculated as a change in pupil radius (see Figure 1b). That is, emotional reactivity at each time point was the difference between pupil radius after each image in window from 1,500 to 2,500 ms after picture onset and the mean of pupil radius at baseline (i.e., from 0 to 1,000 ms from picture onset). Since pupil radius of the right and left eye were strongly intercorrelated ($r = .93$), only the radius of participants' right eye was used in the analyses.

RESULTS

Preliminary Analyses

Consistent with our efforts to control luminosity, there were no significant differences in the amplitude of the initial light reflex as a function of picture emotionality. In Figure 1b, the interquartile range shows a considerable amount of inter-individual and inter-picture variability (to give a clearer view of such variability, we used interquartile range rather than standard error due to the large amount of observed data at each time point, i.e., approximately 1,700). However, the waveforms did not overlap and maintained a monotonic order during the entire time window, thus supporting the validity of the detected signal.

Pupil radius following the initial light reaction was significantly affected by picture emotionality from about 1,500 ms until the end of the viewing interval, as illustrated in Figure 1a. In order to assess the effect of picture valence (i.e., pleasant, unpleasant, and neutral), a mixed effects model was performed with emotional reactivity (i.e., pupillary change computed as the difference between pupil radius between 1,500 and 2,500 ms and baseline) as the dependent variable, emotional valence as a fixed effect, and subjects as a random effect. Results indicated a significant main effect of picture valence, likelihood ratio test: $\chi^2(2) = 39.52$, $p < .001$. Planned comparisons indicated that unpleasant pictures prompted relative increases in pupil radius that were larger than those elicited when viewing neutral pictures ($p = .001$, Cohen's $d = .50$) and pleasant pictures ($p = .001$, Cohen's $d = .88$). Furthermore, pleasant pictures prompted relative decreases in pupil radius that were smaller than those elicited when viewing neutral pictures ($p = .001$, Cohen's $d = -.33$).

Despite these differences in pupil response in relation to valence, Pearson's correlations revealed a significant positive

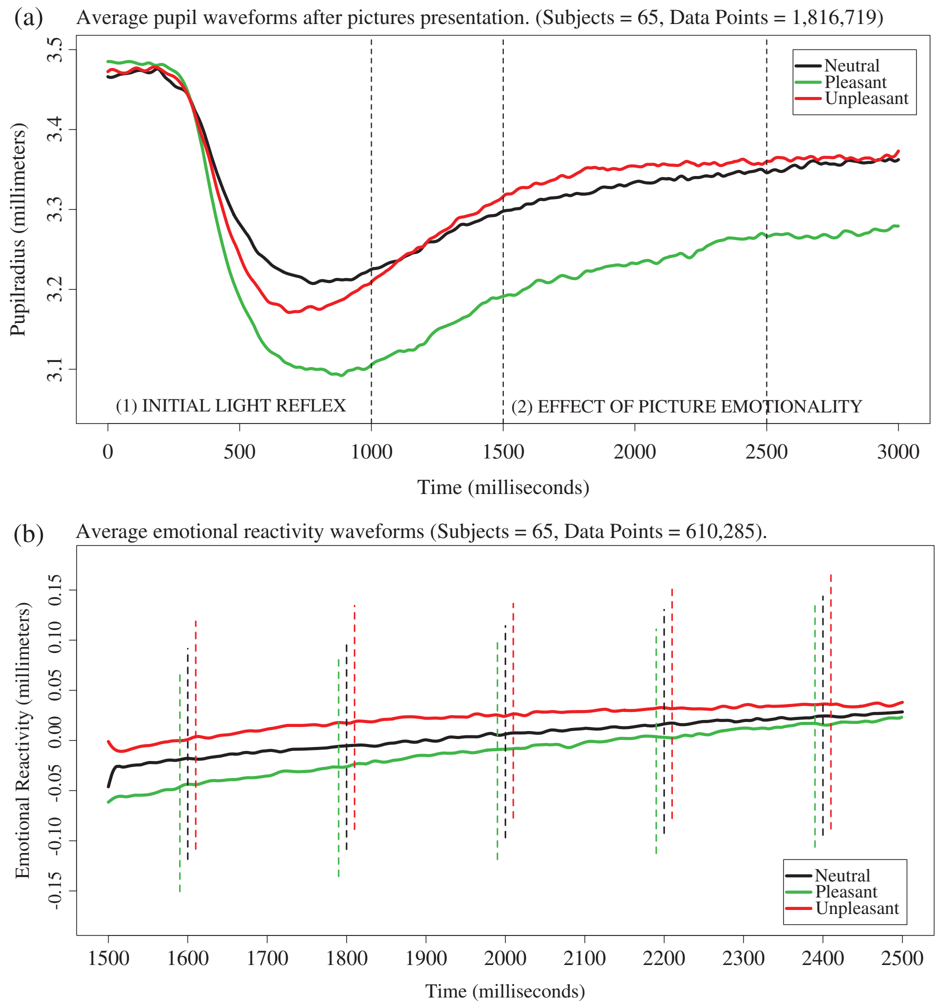

Fig. 1. Graphical representation of observed pupil dilation by type of picture (a) and emotional reactivity (b). Waveforms were calculated using smoothing splines. To highlight inter-individual and inter-stimulus variability, interquartile ranges at 1600, 2000, 2400, and 2600 ms are presented (b).

association between emotional reactivity in response to pleasant and unpleasant stimuli, $r(67) = .85$, $p < .001$, as well as pleasant and neutral stimuli, $r(67) = .77$, $p < .001$ and neutral and negative stimuli, $r(67) = .83$, $p < .001$.

Identification of Pupillary Change Patterns

We performed hierarchical cluster analysis to examine whether there were subgroups of students with reliably distinct patterns of pupillary changes in response to pleasant, unpleasant, and neutral pictures and, if so, to determine in what particular way these clusters differed.

Cluster analysis is a data-driven technique, which allows to discover subgroups of subjects within a data set based on the similarity of their responses. In the current study, we used this approach because the examination of patterns is a useful tool to more accurately understand each student's responding to emotional stimuli of different valence. Changes in pupil radius in response to pleasant, unpleasant, and neutral pictures were used as clustering variables, the squared Euclidean distance as a measure of dissimilarity, and Ward's method was applied. The analysis was conducted through the *hclust* function available in R software (R Development Core Team, 2013).

Cluster analysis identified three distinct groups according to students' pupillary change in response to emotional stimuli (see Figure 2). The three groups were compared on changes in pupil radius in response to pleasant, unpleasant, and neutral pictures (see Figure 3) using multivariate analysis of variance (MANOVA). We found a significant overall effect of cluster group, $F(6, 122) = 16.3$, $p < .001$. Follow-up univariate analysis of variance indicated that the identified groups differed on the pleasant ($F(2, 62) = 93.2$, $p < .001$, $\eta^2 = .75$), unpleasant ($F(2, 62) = 73.2$, $p < .001$, $\eta^2 = .70$), and neutral ($F(2, 62) = 33.1$, $p < .001$, $\eta^2 = .52$) stimuli. As shown

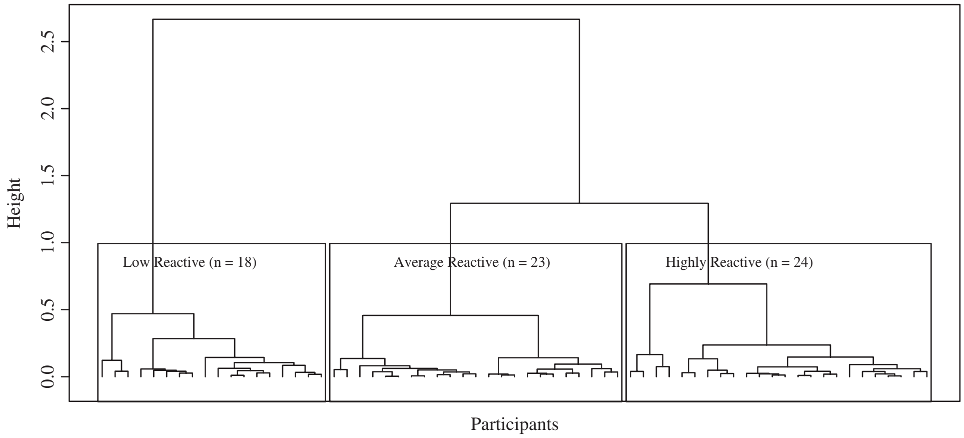

Fig. 2. Dendrogram resulting from cluster analysis on emotional reactivity after viewing pleasant, unpleasant, and neutral pictures ($n = 65$).

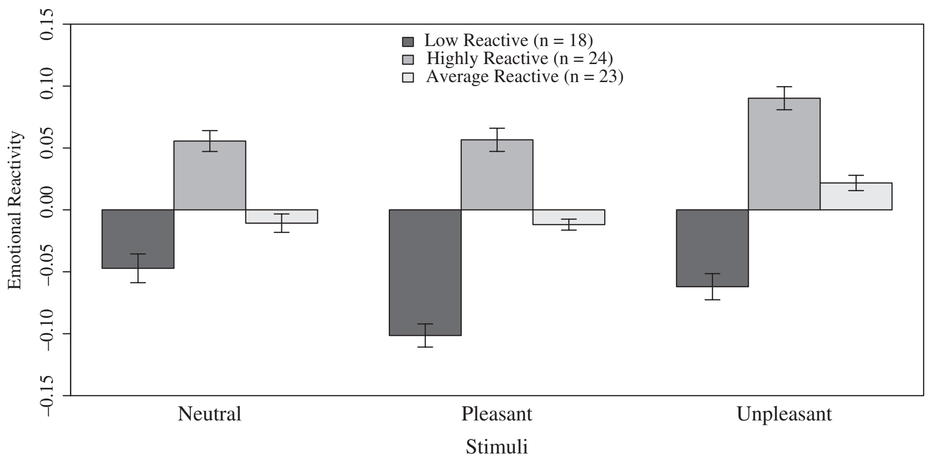

Fig. 3. Profiles of the three emotional reactivity groups resulting from cluster analysis. Error bars represent standard errors of associated means ($n = 65$).

in Figure 3, the first group showed smaller changes in pupil radius compared to the other groups; students in the second group were generally very reactive to all stimuli, having larger changes in pupil radius than the other students. Last, reactivity of students in the third group was in between the other two groups. These results therefore guided our labeling of the clusters. A relatively low arousal response characterized the first group ($n = 18$, 28% of students), which was consequently labeled *low reactive*. Relatively high pupillary changes distinguished the second group ($n = 24$, 37% of students); thus, we termed this group *high reactive*. The response of the third group was in between the other two ($n = 23$, 35% of students); hence, this group was labeled *average reactive*. No association emerged between gender and cluster membership (χ^2 (2) = 2.183, $p = .336$; $\Phi_c = .18$). Furthermore, the age of participants did not vary across cluster groups ($F(2, 62) = 1.50$, $p = .294$, $\eta^2 = .04$).

The Emotional Reactivity–GPA Link and the Moderating Role of Self-Esteem and Psychological Distress

Descriptive statistics and correlations between all study variables are shown in Table 1. Multiple regression was used to test the association between students' emotional reactivity and GPA, as well as the hypothesized moderating role of general self-esteem and psychological distress. Because the literature suggests that all variables (i.e., GPA, emotional reactivity, self-esteem, and psychological distress) can differ between males and females, we controlled for gender in all the analyses. All main effects and two-way interactions involving emotional reactivity were simultaneously evaluated (see Table 2).

Results indicated that gender and emotional reactivity group were significantly associated with GPA. Specifically, females had a higher GPA ($M = 28.10$, $SD = 1.66$) than males ($M = 27.10$, $SD = 1.48$). Low reactivity was associated with higher GPA ($M = 28.43$, $SD = 1.42$) compared to average

Table 1
Descriptive Statistics and Correlations Between Study Variables ($n = 65$).

	1	*2*	*3*	*4*	*M*	*SD*	*Range*
1. GPA					27.8	1.7	22.5–30.0
2. General self-esteem	−.03				.98	.52	0.1–2.7
3. Psychological distress	−.10	.23			1.94	.51	1.0–3.2
4.Gender [a]	−.34*	.36*	.00		—	—	—
5. Emotional reactivity [a]	−.43*	.28*	−.03	.27*	—	—	—

Note: Pearson correlations were calculated between numerical variables, polyserial correlations between numerical and ordinal variables, and polychoric correlations between ordinal variables.
Gender: 1 = female (71%), 2 = male(29%); Emotional reactivity groups: 1 = low (28%), 2 = average (35%), 3 = high (37%).
[a]Descriptive statistics for categorical variables are reported below.
*$p < .05$.

Table 2
Results of Linear Regression With GPA as Dependent Variable

Variable	B *(SE)*	Omnibus *F (df)*	η^2
Emotional reactivity group		6.56** (2.53)	.036
Average reactive	−2.70 (2.26)		
High reactive	−2.98 (2.35)		
General self-esteem	−.22 (.78)	1.82 (1.53)	.00
Psychological distress	−.14 (.73)	2.29 (1.53)	.00
Gender	−2.56* (.94)	5.26* (1,53)	.12
Emotional reactivity group × General self-esteem		3.43* (2.53)	.11
Average reactive × General self-esteem	−.02 (1.04)		
High reactive × General self-esteem	2.29* (1.05)		
Emotional reactivity group × Psychological distress		1.79 (2.53)	.06
Average reactive × Psychological distress	.05 (.96)		
High reactive × Psychological distress	−1.60 (1.02)		
Emotional reactivity group × Gender		1.81 (2.53)	.06
Average reactive × Male	2.12 (1.21)		
High reactive × Male	1.90 (1.13)		

Note: $N = 65$. Baseline category for Gender was *female*. Baseline category for Emotional reactivity group was *low reactive*. $R^2 = .38$.
*$p < .05$; **$p < .01$.

($M = 27.22$, $SD = 1.52$) and high reactivity ($M = 26.93$, $SD = 1.65$). Furthermore, we found a significant interaction between emotional reactivity group and general self-esteem. To probe the interaction effect, we performed tests of the simple slopes (Aiken & West, 1991). Results showed that the effect was significant for highly reactive students ($B = 2.07$, $SE = .73$, $p = .009$), but not for students with low ($B = -.22$, $SE = .61$, $p = .729$) or average emotional reactivity ($B = -.24$, $SE = .77$, $p = .759$). As can be seen in Figure 4, among students in the high reactive group those who scored higher on self-esteem reported better GPA than those who scored lower on this variable. No significant interaction effect of Emotional reactivity group × Psychological distress was found.

DISCUSSION

The goal of the present study was to investigate the possible association between individual differences in emotional reactivity and academic achievement by assessing whether changes in pupillary responses to emotional stimuli are related to GPA. Moreover, we aimed to examine whether this link was moderated by students' levels of self-esteem and/or psychological distress.

Initial analyses revealed a considerable amount of inter-individual variability in pupil dilation in response to emotional stimuli, thus indicating large individual differences in emotional reactivity. However, waveforms of overall means across participants and images did not overlap and maintained a monotonic order during the entire time window, thus indicating the validity of the detected signal. These findings lend support to previous studies, which consider pupil size variation as an indicator of affective processing, and methodologically suggest that the use of mean values is reliable in terms of identifying differences as a function of picture content. However, further studies should test other analytic methods to more accurately take into account the wide variation among individuals in their pupillary responses to emotionally arousing stimuli.

The subsequent step of our analysis aimed at exploring whether distinct clusters of students, differing in sympathetic reactivity to emotional picture stimuli, could be

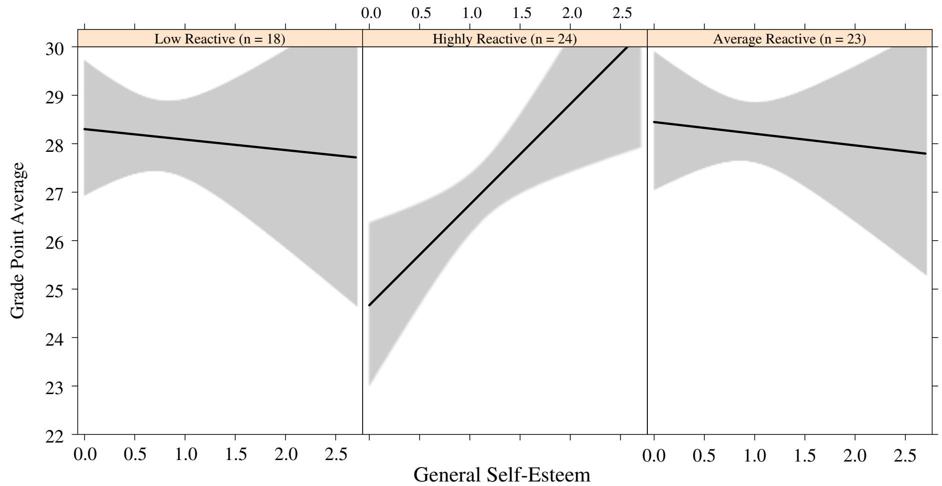

Fig. 4. Interaction plot for general self-esteem and emotional reactivity groups on grade point average. 95% confidence bands are presented in grey ($n = 65$).

identified. Because this analysis was exploratory in nature, we did not formulate any specific prediction as to the number and type of expected groupings. Cluster analysis of pupillary changes in response to pleasant, unpleasant, and neutral pictures yielded a three-group solution. The first group was composed of students with high emotional reactivity, the second group included participants with low responses across all the three valence categories of emotional stimuli, and the third group was comprised of students with average levels of emotional reactivity.

These data, together with the strong positive correlation between emotional reactivity in response to different valenced stimuli, are consistent with the literature reporting that pupillary changes during affective picture viewing are an index of sympathetic activity and thus are determined by emotional arousal and independent from hedonic valence (Bradley et al., 2008). Analyses also indicated that cluster membership was unrelated to gender. Thus, assessing sympathetic reactivity to standardized picture stimuli that vary across the affective dimension of valence (rated arousal was equivalent for pleasant and unpleasant stimuli) allowed us to highlight that undergraduate students in our sample exhibited high, low, or average levels of emotional reactivity when viewing all picture stimuli, regardless of stimulus valence and arousal. The identification of these groups allows us to clarify whether different patterns of emotional sympathetic reactivity among undergraduate students can influence their academic performance.

Previous work on the association between individual differences in emotionality and performance has mainly focused on personality or motivational trait differences in emotional states, for example during and after an examination (Krupić & Corr, 2014). Furthermore, previous studies have suggested that constitutionally based individual differences in the reactivity and regulation of emotions are central to understanding processes of learning in school (Checa, Rodriguez-Bailon, & Rueda, 2008). Yet, to our knowledge, this is the first study assessing individual differences in emotional reactivity in terms of physiological response to emotional pictures, reporting that different profiles of emotional reactivity are associated with students' academic achievement. Students characterized by a higher reactivity to pleasant, unpleasant, and neutral stimuli are the ones reporting a lower GPA compared to average and low reactive students who perform better.

Taken together, these results are consistent with the idea that students with a sympathetic over-reactivity to all environmental stimuli are more at risk of a bad academic performance (Critchley, 2005). It is interesting to note that, apparently, students with worse academic outcomes are the ones who experience emotional situations more intensely than others, regardless of type of stimuli (different valence and arousal). Even if it is important to study domain-specific antecedents of students' emotional experience (Pekrun, 2000; Pekrun, Goetz, Titz, & Perry, 2002), as well as students' reactivity in response to specific learning situations, knowing that undergraduates with higher dispositional emotionality have lower GPA can be important for both theory and practice. The relation between individual differences in response to emotional material encountered outside the academic context and academic performance supports the idea of promoting specific curricula directed to individuals signing up for college who are more prone to be emotionally reactive to everyday pleasant, unpleasant, and neutral stimuli. Being generally over-reactive to their surrounding environment places both male and female undergraduate students in a disadvantaged condition at school. Even though girls perform overall better in their undergraduate courses than their male counterparts (Perkins, Kleiner, Roey, & Brown, 2004), our study did not reveal any interaction effect of emotional reactivity and gender. This is somewhat surprising, since previous data on affective psychophysiology indicate that the most reliable individual difference is related to gender (Lang et al., 1993). It should be noted, however, that this pattern has not been reported for pupillary changes, but only for other peripheral indices (e.g., skin conductance and heart rate variability; Bradley et al., 2001). Moreover, in the preliminary analyses of this work, no association emerged between gender and cluster membership.

The significance of our first finding was amplified by evaluating whether the link between emotional sympathetic reactivity and students' GPA was moderated by general self-esteem and/or psychological distress. Our analyses revealed a significant interaction between emotional reactivity group and general self-esteem; that is, among students with higher emotional reactivity, those with higher self-esteem also reported better academic outcomes, while those with lower self-esteem had a lower GPA. Hence, the relationship between emotional reactivity and GPA was moderated by students' general self-esteem, but only among highly reactive participants. In contrast, among students with low and average levels of emotional reactivity, self-esteem did not have any significant effect. These findings extend prior work on the link between self-esteem and various academic outcomes (Zeigler-Hill et al., 2013). Self-esteem is thought to be important for academic performance because it allows individuals to persist in the face of failure or struggle, which is often associated with early learning stages (Brown, 2010; Zeigler-Hill, 2011). High levels of self-esteem may enhance coping (Arndt & Goldenberg, 2002) and buffer individuals from the consequences of negative experiences, also in relation to academic performance (see Baumeister et al., 2003 for a review). Indeed, among highly reactive students, self-esteem seems to play a similar role by moderating the link between reactivity and performance.

Last, it is worth discussing the lack of a main effect as well as a moderation effect of psychological distress in the link between emotional reactivity and students' GPA. The reason psychological distress does not seem to play a role as a risk factor for college students may be that the anxiety and depression symptoms are overall scarce since we considered a nonclinical population. Previous studies have taken into account students with clinical levels of internalizing problems (Duchesne et al., 2008), or emotional hyper-reactivity to visual stimuli, whereas the low levels of psychological distress characterizing the students taking part in our study where probably not sufficiently relevant to play a role as risk factors.

The study has some limitations that should be considered when interpreting the findings. The first concerns the reliance on a single physiological measure (i.e., pupillary change) as an autonomic indicator of emotional responding that might be related to GPA. Concurrent assessment of different domains of students' emotional response (i.e., subjective, behavioral, and physiological responses) would help better elucidate the complexity of this link. In particular, the recording of both central and (multiple) peripheral measures of physiological responding during different emotional tasks would be especially valuable. A second limitation of this study is the limited number of participants, and further research on larger numbers of students is needed to increase the generalizability of our findings. Furthermore, the study cannot demonstrate any causal relationships among the variables under consideration. A fourth limit is that variables other than those considered may be relevant when studying the link between emotional reactivity and academic achievement. For example, motivational factors, students' approaches to learning, self-regulatory learning strategies, and psychosocial contextual influences (see Richardson et al., 2012 for a review) could be examined in further research. The role of more domain-specific constructs related to GPA should also be investigated. For example, emotional reactivity before, during, or after a test while controlling for test anxiety could be investigated as an important predictor of academic functioning.

Despite these caveats, the findings of the present investigation add to the existing literature by documenting the importance of differences in students' emotional reactivity in relation to academic success. Moreover, not all students are equally susceptible to the negative effects of being highly reactive to emotional material on GPA. Specifically, among students with sympathetic over-reactivity to environmental stimuli, those with low self-esteem are particularly at risk for a scarce performance during their undergraduate studies. These findings should be taken into consideration also for their educational significance. In order to improve students' academic performance effort should be placed in promoting their general self-esteem, specifically among undergraduates who have a tendency to be more reactive to all emotional stimuli in their environment.

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