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The role of achievement emotions for text comprehension and metacomprehension

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Abstract
When learning from text, it is important that learners not only comprehend the information but also accurately monitor and judge their comprehension, known as metacomprehension accuracy. We investigated the extent to which the achievement emotions high school students ($N = 358$) experienced during reading influenced their text comprehension, metacomprehension judgments, and metacomprehension accuracy. The results of our correlational analyses indicated that more negative emotions (i.e., anger, hopelessness, and negative emotions overall) were related to poorer text comprehension (small to small-to-medium correlations). Moreover, the students generally used their emotions as cues for making predictions and postdictions about their comprehension (small to medium-to-large correlations). However, concerning prediction accuracy, more positive emotions (i.e., enjoyment, hope, pride, and positive emotions overall) were associated with greater overconfidence and more negative emotions (i.e., anxiety, shame, and hopelessness) with greater underconfidence (small to small-to-medium correlations). Concerning postdiction accuracy, more positive emotions (i.e., enjoyment, hope, pride, and positive emotions overall) were associated with less underconfidence and more negative emotions (i.e., anxiety and shame) with greater underconfidence (small correlations). The results of our cluster and variance analyses largely converged with the correlational results. Consequently, achievement emotions do not necessarily represent valid cues for judging comprehension and can lead to inaccurate metacomprehension, hindering effective self-regulated learning from texts.

Keywords Achievement emotions · Judgments of comprehension · Metacomprehension accuracy · Text comprehension

A great deal of instruction occurs via text. When learning from text, it is not only important that learners achieve good comprehension but also that they accurately monitor and judge their comprehension, known as metacomprehension accuracy. More accurate metacomprehension leads to more effective regulation of one's learning and in turn to enhanced

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comprehension (e.g., Dunlosky & Rawson, 2012; Thiede et al., 2003). However, learners' metacomprehension is often inaccurate. Particularly with regard to their predictions, which are judgments provided after reading but before testing, learners tend to be overconfident (e.g., Maki et al., 2005; Zhao & Linderholm, 2011). In contrast, postdictions, which are judgments provided after testing, are typically more accurate (e.g., Pierce & Smith, 2001) or even underconfident (e.g., Prinz et al., 2019). According to the cue-utilization framework (Griffin et al., 2009; see also Koriat, 1997), when providing judgments, learners infer their level of comprehension based on available information, known as cues. For example, learners sometimes use their familiarity with the content domain as a cue (e.g., Glenberg et al., 1987).

Although educational settings are infused with emotions, their potential role as judgment cues is largely unclear (see Prinz et al., 2019, for an exception with regard to affect). Achievement emotions in particular occur in relation to achievement activities, like studying and taking tests, and to the outcomes of these activities, that is, success or failure (e.g., Pekrun, 2006). Despite the importance of comprehending texts and accurately judging one's comprehension on the one side and the prominent influence of emotions on cognitive processes on the other side, prior research has seldom examined the association between achievement emotions and comprehension or metacomprehension. Therefore, the present study extends prior research by investigating to what extent positive and negative achievement emotions relate to comprehension and metacomprehension with regard to the magnitude and accuracy of predictions and postdictions. Specifically, the study focuses on accuracy in terms of bias, which reflects the difference between a learner's judged and actual comprehension and indicates over- and underconfidence (e.g., Schraw, 2009). Furthermore, metacomprehension research predominantly consists of experimental studies conducted with college students in the laboratory (see, e.g., De Bruin & van Gog, 2012; Prinz et al., 2020a). Hence, by examining adolescent learners in an ecologically valid setting during a regular classroom session, the study further broadens the existent evidence.

Achievement emotions and text comprehension

Achievement emotions (like emotions generally) are often distinguished into two dimensions, namely valence (positive vs. negative) and activation (activating vs. deactivating; e.g., Pekrun et al., 2007). Combining these dimensions renders four categories of emotions that differ in their impact on learning. Positive-activating emotions (e.g., enjoyment, hope, and pride) typically support attention and motivation, facilitating learners' academic achievement. On the contrary, negative-deactivating emotions (e.g., boredom and hopelessness) normally reduce attention and motivation, impairing learners' academic achievement. For the remaining two categories, the effects are somewhat more variable. Positive-deactivating emotions (e.g., relaxation and relief) might reduce attention and immediate motivation, but can strengthen long-term motivation. Negative-activating emotions (e.g., anger, anxiety, and shame) might likewise reduce attention (e.g., due to worries about failure) and intrinsic motivation, but can trigger extrinsic motivation to avoid failure. Notwithstanding the aforementioned differences with regard to some cognitive processes, overall, positive-deactivating emotions mostly have a positive impact and negative-activating emotions a negative impact on academic achievement. This implies that positive achievement emotions generally predict high academic achievement and negative achievement emotions low academic achievement (e.g., Goetz & Hall, 2013; Pekrun et al., 2007, 2017).

Concerning the influence of achievement emotions on learning from text in particular, the evidence is rather scarce but yields a similar picture. With regard to state emotions, which are momentarily experienced emotions, it has been shown that greater interest and less boredom after reading the first part of a text led to greater persistence and in turn to superior comprehension (Ainley et al., 2002a, b). Moreover, when learners experienced greater anxiety after reading a text, they achieved poorer comprehension (Miesner & Maki, 2007). Similarly, concerning trait emotions, which are habitual, recurring emotions, learners with higher test anxiety achieved poorer comprehension (Miesner & Maki, 2007). Zaccoletti et al. (2020) investigated positive and negative trait achievement emotions that learners feel when engaging in reading comprehension activities. They found that negative-activating (i.e., anxiety, anger, and shame) and negative-deactivating (i.e., boredom and hopelessness) emotions were associated with poorer comprehension (although high updating ability protected learners from the detrimental impact of negative-activating emotions). For positive emotions, the influence on comprehension was less clear but tended to be positive. Thus, although there is not much research examining the impact of achievement emotions on text comprehension, the existent evidence suggests that typically positive achievement emotions facilitate and negative achievement emotions impair comprehension, irrespective of whether the emotions are activating or deactivating.

Achievement emotions and metacomprehension

The association of achievement emotions with metacomprehension has hardly been investigated either. An exception is the study by Miesner and Maki (2007), which focused on the role of learners' trait and state anxiety for metacomprehension judgments and accuracy. First, concerning trait test anxiety, the results revealed that learners with greater anxiety made lower predictions and postdictions. Moreover, when applying a median split, the results indicated that learners with both low and high levels of test anxiety overestimated their comprehension in their predictions and tended to provide somewhat more accurate postdictions. Because anxiety was examined as a dichotomous variable, however, it remains unclear to what extent the accuracy of the predictions and postdictions changes with varying levels of anxiety. Second, with regard to state anxiety reported after reading a text, the results showed that the learners made lower predictions regarding texts for which they experienced higher anxiety. The impact of state anxiety on the accuracy of predictions as well as on postdictions and their accuracy was not reported. Besides anxiety, the impact of achievement emotions on metacomprehension is unclear.

Prinz et al. (2019) experimentally induced affect by means of music and the autobiographical recollection method and looked at its impact on text comprehension and metacomprehension. Descriptively, learners in a positive affective state achieved poorer comprehension but made higher predictions than learners in a negative affective state. As a result, a positive affective state led to overconfident predictions, whereas a negative affective state led to accurate predictions. Postdictions and their accuracy did not significantly differ between the affective states. In tendency, however, postdictions were quite accurate for learners in a positive affective state but underconfident for learners in a negative affective state. Nevertheless, an induced affective state might qualitatively differ from achievement emotions that emerge naturally in an achievement situation. Thus, to what extent the described effects of induced affect transfer to achievement emotions is unclear.

The present study

The present study is the first to investigate to what extent positive and negative achievement emotions experienced during reading affect text comprehension as well as the magnitude and accuracy of metacomprehension judgments (i.e., predictions and postdictions). We examined this issue in a field setting with senior high school students. The last years of high school represent a critical phase in students' educational careers, as they are about to experience the transition to higher education or vocational training. Academic demands become more challenging, and students' success determines which course of study or vocational training program they can enroll in. Hence, both students' emotional experiences and self-regulated-learning skills, such as accurately judging their comprehension, gain in importance, rendering it particularly crucial to investigate them in this context.

We examined state rather than trait emotions because they might be quite salient to learners in a specific situation and thus more likely to be used as judgment cues. Moreover, state emotions are easier to modify, which has beneficial implications for instruction. Emotional experiences in academic contexts are usually complex, and students can perceive a range of different emotions (e.g., Pekrun et al., 2002). Therefore, we considered several achievement emotions that often occur during learning. In addition, we explored the joint influence of positive and negative achievement emotions with cluster and variance analyses.

Previous research has suggested that achievement emotions affect learning from text, with positive emotions exerting positive effects and negative emotions negative effects (e.g., Ainley et al., 2002a). Hence, we expected that more positive emotions would be related to better text comprehension and more negative emotions to poorer text comprehension (comprehension hypothesis).

Moreover, research has indicated that learners use their achievement emotions such as their anxiety as a cue to predict their comprehension, with higher anxiety going along with lower predictions (Miesner & Maki, 2007). Thus, we expected that more positive emotions would be associated with higher predictions and more negative emotions with lower predictions (prediction hypothesis).

With regard to postdictions, it has been shown that learners with higher trait test anxiety made lower postdictions (Miesner & Maki, 2007). We expected that also concerning state achievement emotions more positive emotions would be associated with higher postdictions and more negative emotions with lower postdictions (postdiction hypothesis).

Regarding metacomprehension accuracy, the evidence is particularly scarce. It might be the case that higher predictions in the event of more positive emotions sometimes represent overly optimistic judgments, and lower predictions in the event of more negative emotions overly pessimistic judgments. Accordingly, it has been shown that compared with a negative affective state, a positive affective state resulted in overconfident predictions (Prinz et al., 2019). Therefore, we assumed that more positive emotions would relate to more overconfident predictions, whereas more negative emotions would be associated with less overconfident (i.e., more accurate or even underconfident) predictions (prediction-accuracy hypothesis).

Although it has been found that postdiction accuracy did not significantly differ between positive and negative affective states, a negative affective state was associated with underconfident and a positive affective state with more accurate postdictions (Prinz et al., 2019). Therefore, we assumed that more positive emotions would relate to less underconfident (i.e., more accurate or even overconfident) postdictions, whereas more negative emotions would be associated with more underconfident postdictions (postdiction-accuracy hypothesis).

Method

Sample and design

A total of $N = 373$ senior high school students (10^{th} to 13^{th} grade) from Southern Germany participated in this study. Specifically, students from 22 classes in seven schools were tested. All schools were a "Gymnasium", the highest secondary-school track in Germany that prepares students for university education. The students were in the last three years of their secondary education ("gymnasiale Oberstufe"; depending on the school, this is grades 10 to 12 or 11 to 13). Fifteen students were excluded from the analyses because they were non-native German speakers. The remaining $N = 358$ students were 16.97 ($SD = 0.96$) years old on average, and 63% were female (37% male, none non-binary).

The study was approved by the ethics committee of the university the authors were affiliated with and by the governmental institutions of the states in which the participating classes were located (Baden-Wuerttemberg and Rhineland-Palatinate). The students and their parents were informed about the study and gave their written consent. Participation was voluntary and the students could withdraw at any time.

The field study had a correlational design and was conducted in the students' regular biology classes. Achievement emotions during reading were the predictor variables. Text comprehension, prediction and postdiction magnitude and accuracy constituted the dependent variables.

Material and measures

Achievement emotions We assessed participants' state achievement emotions with the Achievement Emotions Questionnaire (Pekrun et al., 2011). Specifically, we used all eight available scales for learning-related emotions, namely enjoyment (6 items), pride (4 items), hope (3 items), anxiety (6 items), anger (5 items), shame (7 items), boredom (9 items), and hopelessness (5 items). These emotions have been found to occur with high frequency and are therefore suggested to have high practical and theoretical relevance (Pekrun et al., 2011; see also Pekrun et al., 2002). The participants were instructed to report how they felt during learning with the text. The instructions were: "Learning in school can induce different feelings. The following statements refer to the *emotions* you may have experienced *while learning with the text you just read*. Please indicate how you felt during learning." For example, an item assessing enjoyment was "I enjoyed the challenge of learning the material", and an item assessing anger was "I got angry while studying". The participants indicated their agreement with each item on a 5-point Likert scale ranging from 1 (*strongly disagree*) to 5 (*strongly agree*). Scores on the respective items were averaged to generate the eight emotion scales. In addition, composite scales for positive and negative achievement emotions were created by averaging the scores on all items assessing positive and negative emotions, respectively. Specifically, we merged the items on enjoyment, hope, and pride into one variable reflecting positive emotions and the items on anger, anxiety, shame, boredom, and hopelessness into another variable reflecting negative emotions. We decided to combine the activating and deactivating negative emotions into one scale because both have been found to impair learners' attention and intrinsic motivation (although negative-activating emotions can lead to greater extrinsic motivation) and to exert detrimental effects on learners' academic achievement (e.g., Pekrun et al., 2017) and text comprehension (e.g., Zaccoletti et al., 2020). Further supporting this decision, the correlations of the

activating and deactivating negative emotions with the dependent variables appeared similar in our study. In addition, previous (e.g., Pekrun et al., 2011, 2017) as well as our correlational analyses (see Table 1) revealed that the associations between negative-activating and negative-deactivating emotions were generally comparable to the associations within the two emotion categories. Furthermore, we did not assess deactivating positive emotions such as relief or relaxation, because these emotions occur after a study activity is finished rather than during the activity per se. Accordingly, the Achievement Emotions Questionnaire does not include items assessing positive-deactivating emotions experienced during learning (Pekrun et al., 2011). Overall, the positive and negative composite scales provide a more parsimonious description of students' emotional state. Correspondingly, relevant prior research on achievement emotions has likewise built these two scales (e.g., Pekrun et al., 2017). Internal consistency for the scales was acceptable to excellent (see Table 2).[1]

Text comprehension The expository science text used in this study dealt with the biological topic of population dynamics and included 580 words (cf. Prinz et al., 2019). This topic was not part of the participants' regular biology curriculum. Therefore, the text should have provided novel information. The text primarily concerned the Lotka-Volterra model, which is composed of different equations that describe predator–prey dynamics. Comprehension of the text was assessed with five questions that had a multiple-choice format with three response options. The questions required inferences and application of the textual information. The participants received 1 point for each correct answer.

Metacomprehension judgments Metacomprehension judgments were assessed in terms of predictions and postdictions. When making predictions, the participants estimated the number of comprehension questions they believed they would answer correctly before completing the questions. When making postdictions, the participants estimated the number of comprehension questions they believed they had answered correctly after completing the questions.

Metacomprehension accuracy Metacomprehension accuracy was computed for predictions and postdictions. Metacomprehension accuracy was operationalized in terms of bias, that is, the magnitude and direction of the difference between a participant's estimated and actual number of correctly answered comprehension questions (see, e.g., Schraw, 2009). Positive values indicated overconfidence and negative values underconfidence.

Prior knowledge Prior knowledge was assessed with one open-ended question that asked participants to write down everything they know about population dynamics. They received 1 point for providing a rough definition of what population dynamics are and 2 points for additionally providing a more detailed explanation of predator–prey relationships. Two raters independently scored the participants' answers with high inter-rater agreement, Cohen's $\kappa = .90$, 95% CI [.83, .97].

[1] In an exploratory manner, we also assessed the achievement emotions the participants experienced during testing. However, it is particularly difficult to infer an effect direction for these emotions. Specifically, predictions were made before testing and hence before the test-related emotions were experienced. In addition, completing the test questions (i.e., performance) occurred before the participants indicated their test-related emotions. Thus, these emotions cannot be validly related to performance, predictions, prediction accuracy, and postdiction accuracy (because the accuracy measures are composed of the performance variable in addition to the respective judgment variable). Nevertheless, data on the test-related emotions are provided in Appendix A for interested readers.

Table 1 Correlations among the achievement emotions and dependent variables

Achievement emotion	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1. Enjoyment	-														
2. Pride	.66**	-													
3. Hope	.65**	.61**	-												
4. Anxiety	.04	.21**	-.08	-											
5. Anger	-.28**	-.07	-.31**	.41**	-										
6. Shame	.04	.24**	-.13*	.69**	.39**	-									
7. Boredom	-.48**	-.23**	-.41**	.12*	.62**	.21**	-								
8. Hopelessness	-.08	.11*	-.21**	.72**	.51**	.66**	.29**	-							
9. Positive emotions	.92**	.86**	.82**	.07	-.25**	.07	-.43**	-.06	-						
10. Negative emotions	-.31**	-.02	-.38**	.66**	.77**	.70**	.75**	.72**	-.26**	-					
11. Text comprehension	.04	-.04	.01	-.10†	-.12*	-.09	-.08	-.19**	.01	-.14*	-				
12. Prediction magnitude	.21**	.11*	.28**	-.38**	-.19**	-.40**	-.10†	-.44**	.23**	-.34**	.16*	-			
13. Postdiction magnitude	.20**	.14*	.22**	-.28**	-.16*	-.27**	-.13*	-.34**	.21**	-.29**	.25**	.48**	-		
14. Prediction accuracy	.13*	.12*	.19**	-.16*	-.03	-.18**	<-.01	-.12*	.16*	-.10†	-.73**	.52**	.09†	-	
15. Postdiction accuracy	.12*	.14*	.16*	-.11*	-.03	-.13*	-.04	-.09†	.15*	-.10†	-.67**	.21**	.50**	.71**	-

*$p < .05$

**$p < .001$

†$p < .10$

Procedure

First, the participants completed the prior knowledge test. Then, they had 10 min to read the text about population dynamics. They were told that their comprehension of the text would be tested after reading. Afterwards, the participants reported the emotions they had experienced during reading. Following that, they predicted their comprehension. For this, they were informed about the kind, format, number, and amount of time available for the upcoming comprehension questions. Thereafter, the participants answered the comprehension questions within 10 min. Finally, they postdicted their comprehension and answered some demographic questions. Prior research has shown that the amount of time learners are allocated for reading a text and answering test questions on it (i.e., time pressure vs. taking as much time as they like) can affect comprehension and metacomprehension processes (e.g., Ackerman & Lauterman, 2012). We set the time for reading and for taking the test to 10 min each, because pilot testing had revealed that this was an adequate amount of time. Specifically, it did not induce high time pressure but prevented participants from disengaging with the respective task. The experimenter announced when half of the time had elapsed and when there was one minute left. The entire session took about 45 min (i.e., one school lesson). All participants were treated in a manner consistent with the ethical standards of the American Psychological Association.

Results

Descriptive statistics for the study variables are presented in Table 2. We converted the dependent variables to percentages to facilitate interpretation (prediction and postdiction accuracy are reported in percentage points, that is, the difference between the

Table 2 Descriptive statistics for the achievement emotions, prior knowledge, and dependent variables

Variable	*M*	*SD*	Cronbach's α
Enjoyment	3.18	0.81	.84
Pride	2.94	0.85	.71
Hope	3.29	0.88	.72
Positive emotions	3.13	0.74	.90
Anxiety	1.72	0.73	.79
Anger	1.56	0.59	.71
Shame	1.76	0.74	.82
Boredom	2.09	0.85	.91
Hopelessness	1.44	0.62	.83
Negative emotions	1.76	0.55	.92
Prior knowledge	0.10	0.30	
Text comprehension (in %)	63	23	
Prediction magnitude (in %)	68	19	
Postdiction magnitude (in %)	54	21	
Prediction accuracy (in %)	5	27	
Postdiction accuracy (in %)	-10	27	

judgment in percent and performance in percent). The participants' average comprehension performance was 63%. The participants provided lower postdictions compared with their predictions. This difference was statistically significant, $t(357) = 13.39$, $p < .001$, $d = 0.71$. Predictions were slightly overconfident (5%) and differed significantly from zero, $t(357) = 3.13$, $p = .002$, $d = 0.17$, whereas postdictions tended to be underconfident (-10%), also differing significantly from zero, $t(357) = -6.77$, $p < .001$, $d = 0.36$. The difference between prediction and postdiction accuracy was statistically significant (the same t-value as for the comparison of predictions and postdictions applies because the accuracy measures reflect the difference between judgments and performance, where performance is always the same variable). Note that the participants did not experience a very high degree of negative emotions. Therefore, a high degree of negative emotions must be interpreted relatively. In addition, as expected, the participants' prior knowledge concerning the topic was very low, with none of the participants achieving the maximum of 2 points.

In the following results section, we first report the correlations between the achievement emotions and the dependent variables. Then, to untangle how different emotion patterns affect the outcomes, we report cluster and variance analyses.

Associations between achievement emotions and text comprehension, metacomprehension judgments, and metacomprehension accuracy

Because the data are hierarchically structured, we first examined the impact of group membership on the dependent variables. Specifically, we calculated the intraclass correlation coefficient ICC(1), which reflects the proportion of variance in a dependent variable that is attributable to between-groups differences. In doing so, we focused on differences between classes (i.e., 22 classes). Higher ICC(1) values indicate that a greater proportion of the variation in the dependent variable is due to group membership. According to current recommendations, values higher than .05 indicate that traditional regression-based approaches are inappropriate and that multilevel modelling should be applied (Heck et al., 2014). In the present study, for all dependent variables, the ICC(1) was lower than .05 (see Table 3), demonstrating that the affiliation with a specific class explained very little variance in the dependent variables. Therefore, we refrained from conducting multilevel analyses and examined the correlations between the achievement emotions and the dependent variables, which are presented in Table 1.

Some of the negative emotions showed deviations from normality, as very high values were rather scarce and thus tended to constitute outliers. Therefore, we report Spearman correlations. Values of .01, .03, and .05 represent thresholds for small, medium, and large effects, respectively (Cohen, 1988).

Table 3 ICC(1)s for the dependent variables

Dependent variable	ICC(1)
Text comprehension	.039
Prediction magnitude	.046
Prediction accuracy	.032
Postdiction magnitude	.023
Postdiction accuracy	.014

Achievement emotions and text comprehension Anger and hopelessness were negatively correlated with text comprehension, as were negative emotions overall. Thus, although it should be noted that the correlations were of rather small size, in line with the comprehension hypothesis, when participants experienced greater anger, hopelessness, and generally negative emotions while studying, they achieved poorer comprehension. Yet, contrary to the comprehension hypothesis, none of the positive emotions were related to text comprehension.

Achievement emotions and predictions All of the achievement emotions except for boredom (marginally significant) were significantly related to predictions. The size of the correlations ranged from small to medium-to-large. The positive emotions (i.e., enjoyment, hope, pride, and positive emotions overall) were positively correlated with predictions, and the negative emotions (i.e., anger, anxiety, shame, hopelessness, and negative emotions overall) were negatively correlated with predictions. Hence, in accordance with the prediction hypothesis, when participants experienced stronger positive emotions, they provided higher predictions, and when they experienced stronger negative emotions, they provided lower predictions.

Achievement emotions and postdictions Similar to the results for predictions, all of the achievement emotions were significantly related to postdictions, with the correlations being of small to medium size. The positive emotions (i.e., enjoyment, hope, pride, and positive emotions overall) were positively correlated with postdictions, and the negative emotions (i.e., anger, anxiety, shame, boredom, hopelessness, and negative emotions overall) were negatively correlated with postdictions. Therefore, supporting the postdiction hypothesis, when participants experienced stronger positive emotions, they provided higher postdictions, and when they experienced stronger negative emotions, they provided lower postdictions.

Achievement emotions and prediction accuracy With the exceptions of anger, boredom, and negative emotions overall (the latter was marginally significant), the achievement emotions were significantly related to prediction accuracy. The positive emotions (i.e., enjoyment, hope, pride, and positive emotions overall) exhibited a positive correlation and the negative emotions (i.e., anxiety, shame, and hopelessness) a negative correlation with prediction accuracy. Although the correlations were of rather small size, this means that in line with the prediction-accuracy hypothesis, with increasing positive emotions, participants' predictions became more overconfident (trajectory from underconfidence to overconfidence). In contrast, with increasing negative emotions, participants' predictions became more underconfident (trajectory from overconfidence to underconfidence; see also Fig. 1).

Achievement emotions and postdiction accuracy Many of the achievement emotions were also significantly related to postdiction accuracy, with the correlations small in size. Specifically, all of the positive emotions (i.e., enjoyment, hope, pride, and positive emotions overall) exhibited a positive correlation with postdiction accuracy. Of the negative emotions, anxiety and shame showed a negative correlation with postdiction accuracy. This indicates that in accordance with the postdiction-accuracy hypothesis, with increasing positive emotions, participants' postdictions became less underconfident (trajectory from underconfidence to greater accuracy). In contrast, with increasing negative emotions, participants' postdictions became more underconfident (trajectory from greater accuracy to underconfidence; see also Fig. 2).

Fig. 1 Relationships between the achievement emotions and prediction accuracy. *Note*. The total scale of prediction accuracy ranges from -100% to + 100%

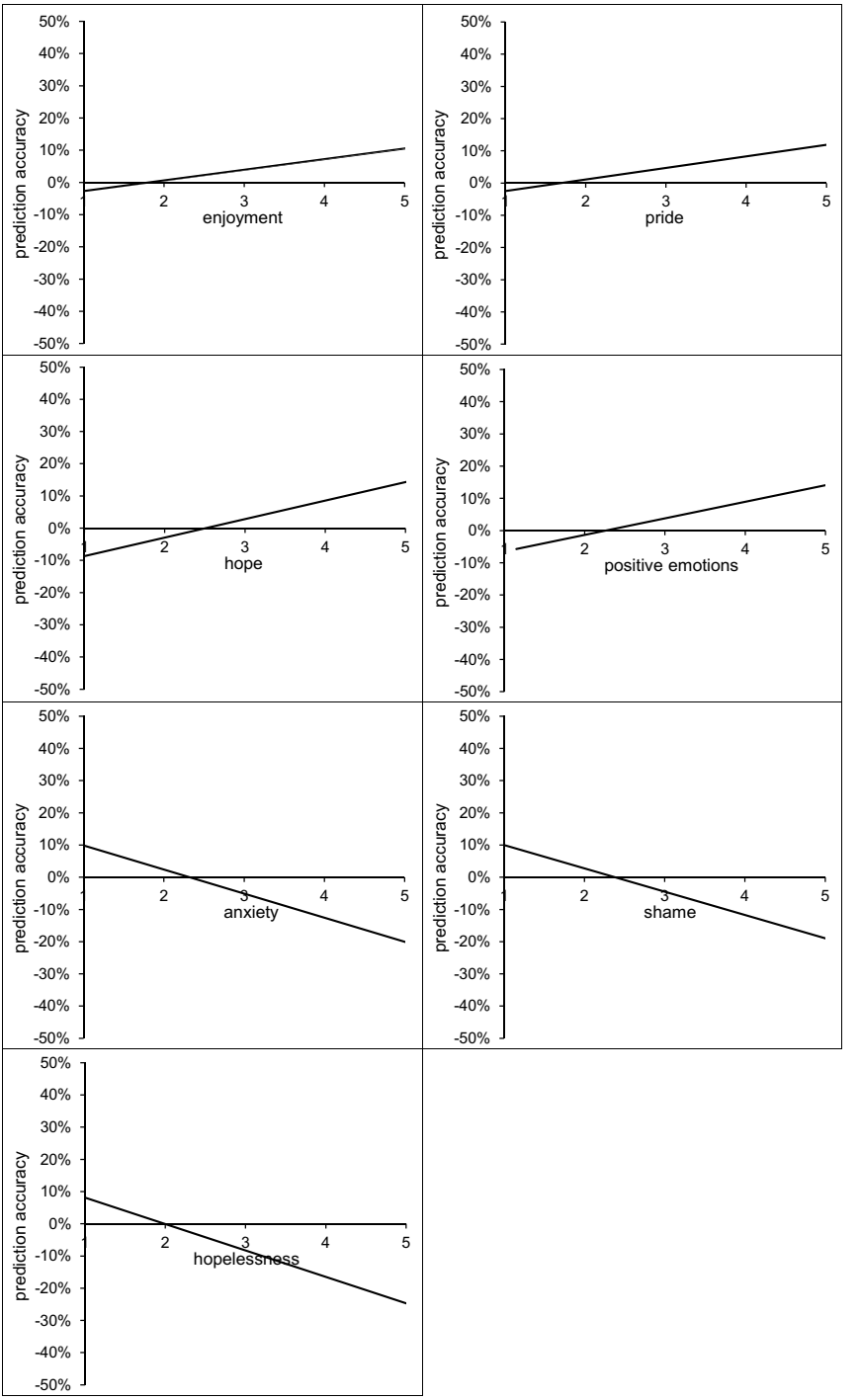
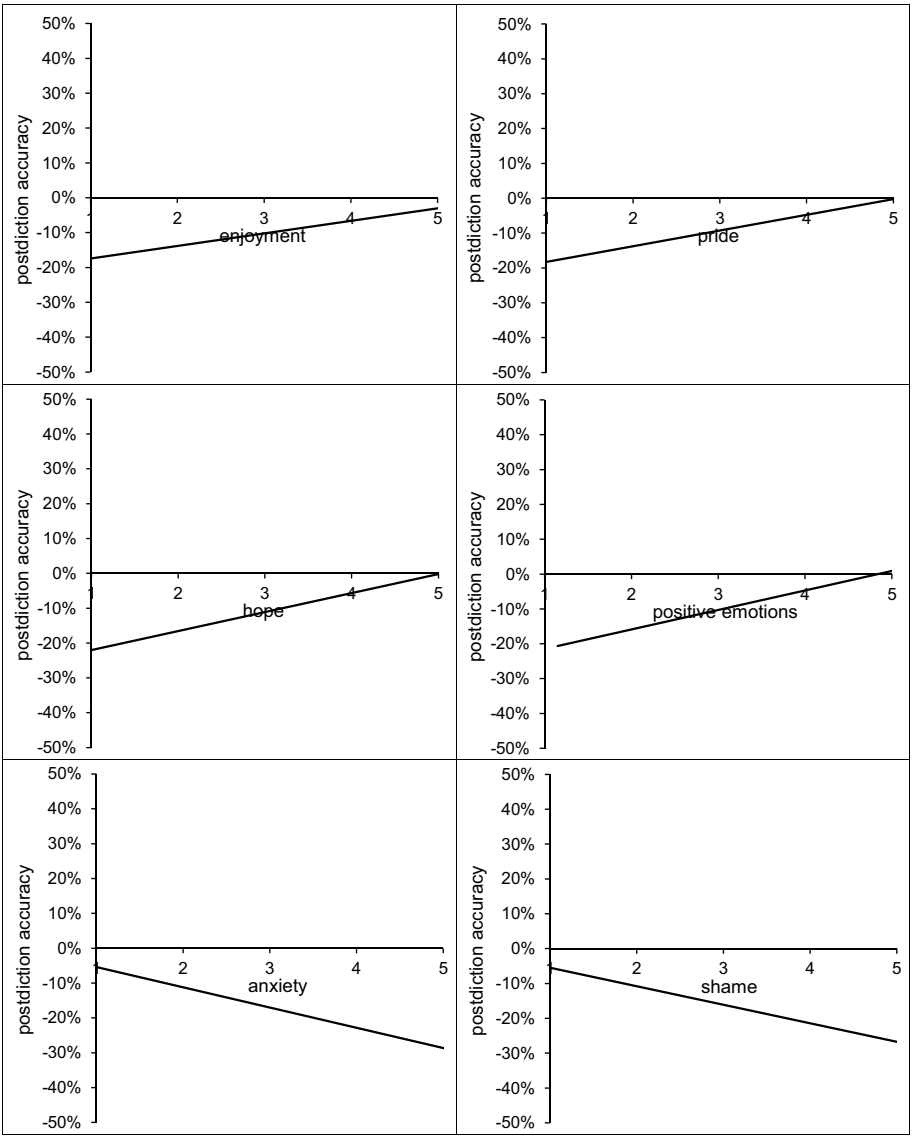


Fig. 2 Relationships between the achievement emotions and postdiction accuracy. *Note*. The total scale of postdiction accuracy ranges from -100% to + 100



The impact of achievement-emotion profiles on text comprehension, metacomprehension judgments, and metacomprehension accuracy

Individuals typically experience a certain degree of positive and negative emotions at a time. Therefore, it seems promising to investigate how different emotion profiles relate to text comprehension, metacomprehension judgments and accuracy. To do so, we first conducted a cluster analysis to establish emotion profiles and then conducted analyses of

variance to examine differences between these profiles in the dependent variables. For the cluster analysis, we used the two composite emotion variables. The negative-emotions variable showed deviation from normality, as there were some outliers, which were excluded from the analyses. After removing the outliers, 343 participants remained in the sample, whose negative emotions ranged from 1.00 to 2.88, with an average of 1.70 ($SD = 0.45$; positive emotions: $M = 3.14$, $SD = 0.74$, range: 1.15 to 4.69). Therefore, as indicated previously, a high degree of negative emotions must be interpreted relatively. For the analyses of variance, if the assumption of homogeneity of variances was not met, we report Welch's F (note that the results of the Welch's test always converged with the ANOVA results). We provide η^2 as the effect size measure. Values of .01, .06, and .14 represent thresholds for small, medium, and large effects, respectively (Cohen, 1988).

Cluster analysis A cluster analysis is an exploratory statistical procedure that groups participants in such a way that participants in the same cluster are more similar to each other (with regard to the variables used in the analysis) than to participants in other clusters. We conducted a hierarchical cluster analysis with the Ward method to establish clusters as a function of positive and negative emotions. The two variables were z-standardized to prevent that different value ranges and variances have differential influences on determining the cluster solution. The Squared Euclidean Distance was used as proximity measure. The results showed that the amount of heterogeneity within clusters increased considerably at the transition from three to two clusters, suggesting a 3-cluster solution, as well as at the transition from two to one cluster, suggesting a 2-cluster solution. This is depicted in the scree plot in Fig. 3. As the first large bend occurred at three clusters, we decided to retain the 3-cluster solution (see, e.g., Bacher et al., 2010). This cluster solution could also be meaningfully interpreted.

To examine the stability of the clusters, we additionally conducted a non-hierarchical cluster analysis with the K-means method and three clusters. The results showed that the clusters were stable, as a similar allocation of participants to three clusters occurred and

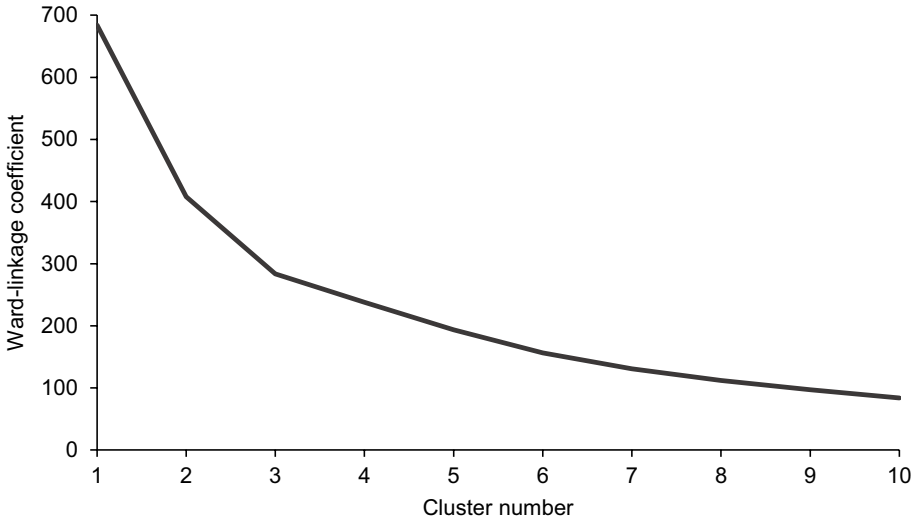


Fig. 3 Scree plot for the cluster analysis

similar cluster centers emerged (i.e., similar means in the clusters concerning the positive- and negative-emotions variables).

As can be seen in the scatterplot in Fig. 4, the three clusters established in the hierarchical cluster analysis differed in terms of participants' emotional experience. The three clusters were named based on their most distinctive feature in comparison to the other clusters. One cluster of $n = 182$ participants was characterized by experiencing a high degree of positive emotions ($M = 3.58$, $SD = 0.50$; range: 2.77 to 4.69). In addition, the degree of negative emotions was low ($M = 1.43$, $SD = 0.25$; range: 1.00 to 2.13). This group is referred to as the *positive group*. Another cluster of $n = 72$ participants was characterized by experiencing relatively low degrees of positive ($M = 2.23$, $SD = 0.29$; range: 1.54 to 2.77) and negative emotions ($M = 1.65$, $SD = 0.28$; range: 1.06 to 2.19). This cluster is called the *neutral group*. Finally, a third cluster of $n = 89$ participants was characterized by experiencing a comparatively high degree of negative emotions ($M = 2.29$, $SD = 0.29$; range: 1.88 to 2.88), while positive emotions tended to be on a medium level and ranged from low to high ($M = 2.99$, $SD = 0.67$; range: 1.15 to 4.38). This cluster is referred to as the *negative group*. Again, it should be noted that the degree of negative emotions in the negative group is still not very pronounced on an absolute level. Moreover, positive emotions in the negative group ranged from low to high (i.e., no separate groups differing in their degree of positive emotions emerged, e.g., no separate negative and negative + positive groups). In contrast, in the positive group, the degree of negative emotions was low (see also Fig. 4). Apparently, when participants experience a relatively high degree of negative emotions, they are fairly comparable, independent of the degree of positive emotions perceived, thus constituting one cluster. The feeling of a negative emotional state might be quite dominant, making it irrelevant to what extent one also experiences positive emotions at the same time. Analyses of variance showed that the differences between groups in the emotion variables were significant for the positive, Welch's $F(2, 181.68) = 359.96$, $p < .001$, $\eta^2 = .52$, as well

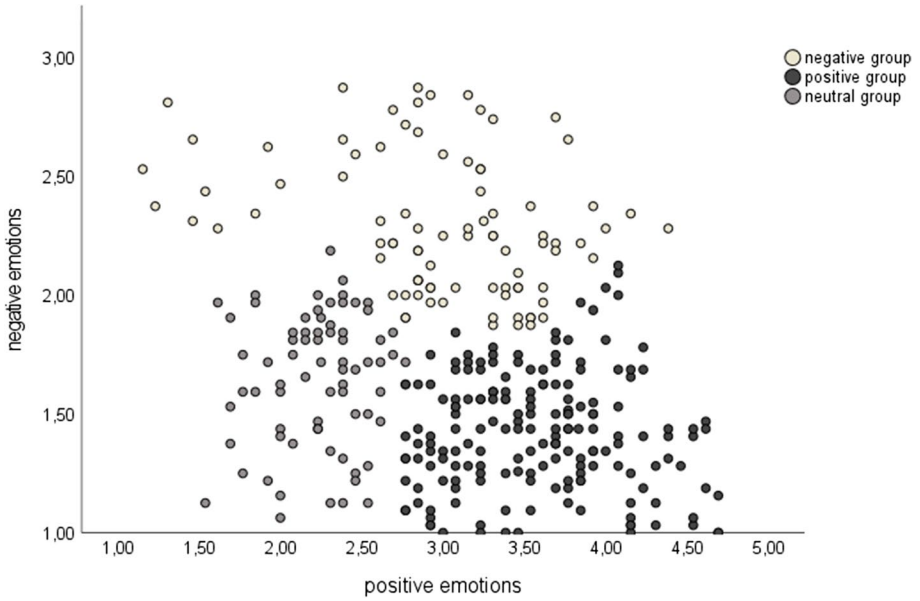


Fig. 4 Scatterplot of the three clusters

as for the negative emotions, $F(2, 340) = 320.45$, $p < .001$, $\eta^2 = .65$. All pairwise comparisons with Bonferroni correction of the α-level were statistically significant (all ps $< .001$).

Differences among the emotion profiles We investigated whether the three emotion-profile groups differed with regard to the dependent variables. Descriptive statistics are provided in Table 4.

A significant overall effect emerged concerning participants' predictions, Welch's $F(2, 156.88) = 13.34$, $p < .001$, $\eta^2 = .07$. The prediction hypothesis proposed that more positive emotions would be associated with higher predictions compared to more negative emotions, which would be associated with lower predictions. With regard to the emotion profiles, this would mean that the positive group should make higher predictions than the negative and neutral groups. Additionally, the neutral group should presumably fall in between the other two groups. This group is characterized by not perceiving positive or negative emotions to a considerable degree and might thus rely on emotions as cues to a lesser extent. We tested these assumptions with planned orthogonal contrasts, which are independent linear comparisons between the conditions of a variable. First, we contrasted the positive group to the negative and neutral groups by using the following contrast weights: positive group: 2, negative group: -1, neutral group: -1. Second, we tested for a potential difference between the latter two groups with the following contrast weights: positive group: 0, negative group: -1, neutral group: 1. In line with the prediction hypothesis, the first contrast showed that participants in the positive group provided higher predictions than participants in the other groups, $t(301,27) = 4.04$, $p < .001$, $\eta^2 = .05$. In addition, participants in the negative group provided lower predictions than participants in the neutral group, $t(144,40) = 2.54$, $p = .012$, $\eta^2 = .02$.

There also appeared to be a significant overall effect concerning participants' postdictions, Welch's $F(2, 153.96) = 17.20$, $p < .001$, $\eta^2 = .09$. The postdiction hypothesis assumed that more positive emotions would be associated with higher postdictions in contrast to more negative emotions, which would be associated with lower postdictions. Thus, concerning the emotion profiles, the positive group should make higher postdictions than the other groups, with the neutral group likely providing postdictions on an intermediate level. We tested this assumption with the previously described planned orthogonal contrasts. In line with the postdiction hypothesis, the first contrast showed that participants in the positive group provided higher postdictions than participants in the other groups, $t(298,22) = 5.05$, $p < .001$, $\eta^2 = .07$. Moreover, participants in the negative group provided lower postdictions than participants in the neutral group, $t(146,99) = 2.28$, $p = .024$, $\eta^2 = .02$.

Table 4 Descriptive statistics for the dependent variables (in %) by emotion-profile group

Variable	Positive group		Neutral group		Negative group		Overall sample	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Text comprehension	64	22	67	21	60	25	64	23
Prediction magnitude	73	17	69	19	61	17	69	18
Postdiction magnitude	60	19	53	22	45	21	54	21
Prediction accuracy	8	26	2	26	2	27	5	27
Postdiction accuracy	-5	25	-14	29	-15	25	-9	26

The overall effect on prediction accuracy was only marginally significant, $F(2, 340) = 2.59$, $p = .077$, $\eta^2 = .02$. Nevertheless, to examine the group differences of interest, we conducted contrast analyses. The prediction-accuracy hypothesis stated that more positive emotions would be associated with greater overconfidence compared with more negative emotions, which should be related to more accurate or even underconfident predictions. For the emotion profiles, this suggests that the positive group should provide more overconfident predictions compared with the negative and neutral groups. Concerning the latter two, the neutral group might provide more overconfident (or less underconfident) predictions compared with the negative group. Again, we tested these assumptions with the planned orthogonal contrasts described above. In line with the prediction-accuracy hypothesis, the first contrast showed that participants in the positive group provided more overconfident predictions than participants in the other groups, $t(340) = 2.26$, $p = .025$, $\eta^2 = .02$. However, there was no significant difference between participants in the negative group and the neutral group, $t(340) = 0.12$, $p = .904$, $\eta^2 < .01$.

Finally, there was a significant overall effect on postdiction accuracy, $F(2, 340) = 6.25$, $p = .002$, $\eta^2 = .04$. The postdiction-accuracy hypothesis proposed that more negative emotions would relate to greater underconfidence compared with more positive emotions, which should be associated with more accurate or even overconfident postdictions. This would mean that the positive group should provide less underconfident (or even accurate or overconfident) postdictions compared with the negative and neutral groups. Concerning the latter two, the neutral group might make less underconfident (or even accurate or overconfident) postdictions compared with the negative group. We tested these assumptions with the described planned orthogonal contrasts. In accordance with the postdiction-accuracy hypothesis, the first contrast showed that participants in the positive group provided less underconfident postdictions than participants in the other groups, $t(340) = 3.50$, $p < .001$, $\eta^2 = .04$. However, the negative group and the neutral group did not significantly differ from each other, $t(340) = 0.22$, $p = .829$, $\eta^2 < .01$.

Concerning accuracy in terms of bias, when an average score such as a group mean is computed, positive and negative values, which indicate over- and underconfidence, respectively, can cancel each other out (note that this is not an issue with correlational analyses). Therefore, we additionally compared the percentages of participants in the three groups who provided overconfident, underconfident, and accurate predictions and postdictions, respectively. The analyses are reported in Appendix B. The results converge with the results described above.

Discussion

Successful learning from text requires that learners comprehend the textual information as well as accurately judge their own comprehension, as the latter is a prerequisite for adaptive regulation (e.g., Dunlosky & Rawson, 2012; Thiede et al., 2003). Thus, it is crucial to generate sophisticated knowledge about factors influencing these processes. The present study addressed this issue by investigating to what extent positive and negative state achievement emotions that learners experience during reading relate not only to their text comprehension but also to their metacomprehension judgments (i.e., predictions and postdictions) and the accuracy of these.

The correlational analyses showed that learners' comprehension was poorer when they experienced greater anger, hopelessness, and generally negative emotions during reading,

whereas positive emotions were not related to comprehension (note, though, that the correlations were rather small and that the analyses with the emotion-profile groups yielded no significant effect). Similarly, in the study by Zaccoletti et al. (2020), who investigated trait achievement emotions, only negative emotions had clear effects on comprehension. Specifically, negative-activating and negative-deactivating emotions were negatively associated with comprehension. Note that also in our study, anger as an activating and hopelessness as a deactivating emotion impaired comprehension. Together, these results suggest that negative achievement emotions might generally produce greater task-irrelevant thinking, leaving fewer cognitive resources for complex comprehension processes (cf., e.g., Ellis & Ashbrook, 1988; Pekrun et al., 2007). In fact, test-related anxiety, anger, shame, and hopelessness were found to be positively correlated with task-irrelevant thinking in previous research (Pekrun et al., 2004). A reason for the limited relation between positive achievement emotions and comprehension could be that although they are associated with less task-irrelevant thinking (Pekrun et al., 2004), learners still have to make efficient use of the freed-up capacity. For instance, positive achievement emotions may only support comprehension if learners use their cognitive resources for important comprehension processes such as drawing relevant inferences. Future studies on the impact of achievement emotions on reading comprehension should examine possible reasons why negative emotions are stronger predictors of learners' comprehension than positive emotions and consider potential intervening variables such as learners' task-irrelevant thinking and inference processes. The unbalanced impact of positive versus negative achievement emotions on learners' comprehension might reflect a general asymmetry in the impact of good versus bad on the human mind and behavior – with bad states and events having greater power (see, e.g., Baumeister et al., 2001).

Furthermore, the results revealed that the learners used the achievement emotions they experienced during reading as cues when making judgments about their comprehension. Miesner and Maki (2007) found that learners provided lower judgments when their anxiety was higher. Our study indicates that not only anxiety, but also various other positive and negative achievement emotions are drawn upon to make predictions and postdictions. Specifically, the correlational analyses showed that the learners made higher predictions and postdictions when they experienced stronger positive emotions, that is, enjoyment, hope, pride, and positive emotions overall. On the contrary, the learners made lower predictions and postdictions when they experienced stronger negative emotions, namely anger, anxiety, shame, hopelessness, boredom (only marginally significant for predictions), and negative emotions overall. The findings for the emotion-profile groups showed a similar pattern, in that the positive group made higher predictions and postdictions than the neutral and negative groups, with the latter providing the lowest judgments. Theoretically, the affect infusion model (specifically the affect-as-information principle, Forgas, 1995; see, e.g., also Schwarz & Clore, 1983, 1988) can help to explain how achievement emotions might be used as cues and affect judgments. It suggests that feelings can influence judgments directly by providing experiential and bodily information concerning how one feels about the object of judgment. That is, when making a judgment, people interpret their preexisting feelings as a reaction to the object of judgment. Consequently, positive emotions lead to positive judgments, whereas negative emotions lead to negative judgments. Accordingly, when their own text comprehension is the object of judgment, learners experiencing more positive emotions during reading tend to make higher judgments, whereas learners experiencing more negative emotions during reading tend to make lower judgments. The latter seems to hold true irrespective of whether the negative emotions are activating or deactivating ones.

However, the use of achievement emotions as cues can apparently impair the accuracy of learners' predictions and postdictions. In fact, the correlational analyses indicated that with respect to prediction accuracy, the learners more strongly overestimated their comprehension when they experienced stronger positive emotions, that is, enjoyment, hope, pride, and positive emotions overall, and more strongly underestimated their comprehension when they experienced stronger negative emotions, namely anxiety, shame, and hopelessness (note that the correlations were rather small). Accordingly, when looking at the emotion-profile groups, the positive group made more overconfident predictions than the negative and neutral groups, where predictions tended to be more accurate and did not differ from each other (note that the overall effect of emotion-profile group on prediction accuracy was only marginally significant). Thus, a higher degree of positive emotions was associated with overconfidence, whereas a higher degree of negative emotions was associated with greater accuracy or underconfidence. Concerning postdiction accuracy, the learners less strongly underestimated their comprehension when they experienced stronger positive emotions, that is, enjoyment, hope, pride, and positive emotions overall, and more strongly underestimated their comprehension when they experienced stronger negative emotions, namely anxiety and shame. Similarly, when looking at the emotion-profile groups, the positive group provided less underconfident postdictions than the negative and neutral groups, which were more underconfident and did not differ from each other. Hence, with regard to the accuracy of postdictions, underconfidence appeared to be a particular issue and was greater with more negative emotions. Overall, the results on metacomprehension accuracy indicate that achievement emotions do not always represent diagnostic (i.e., predictive) cues for learners' actual comprehension. Although the emotions might sometimes be diagnostic of comprehension (i.e., positive emotions are often associated with better and negative emotions with poorer performance), this is not regularly the case. For instance, positive achievement emotions are not necessarily associated with better comprehension, as was also the case in our study (see also Zaccoletti et al., 2020). In addition, learners might overweight the predictive value of their emotions when making judgments, so that more positive emotions result in greater overconfidence and more negative emotions in greater underconfidence, as was found for learners' predictions. Regarding their postdictions, the learners were generally underconfident. Postdictions are made after completing a comprehension test. Thus, the learners had insight into the test questions and might have become more unsure about whether they were able to answer them correctly, especially as they received no feedback concerning their performance. Therefore, they might provide lower judgments, resulting in underconfidence. Moreover, underconfidence seems to be particularly pronounced when learners experience stronger negative emotions. In this case, learners might feel especially doubtful with regard to their achieved comprehension, while overrating the actual diagnosticity of their negative emotions. In contrast, when they experience stronger positive emotions, learners provide higher postdictions and are less underconfident. The finding that underconfidence is exaggerated with more negative emotions is generally in accordance with research on "desirable difficulties", which occur when learning strategies (e.g., retrieval practice) decelerate or hamper the learning process but produce superior long-term performance and transfer (Bjork, 1994). Facing desirable difficulties can induce negative emotions, such as anxiety or anger, which might lead learners to neglect and underestimate the effectiveness of the respective learning strategies (see, e.g., Zepeda et al., 2020). To conclude, when making predictions, it does not seem beneficial for learners to draw on their achievement emotions, because both negative and positive emotions can impair their accuracy. Likewise, when providing postdictions, learners should not rely on their achievement emotions, especially when experiencing

negative emotions, because this can exacerbate underconfidence. To foster accurate judgments and thereby effective self-regulated learning from texts, learners should be supported in focusing on diagnostic cues instead of on their achievement emotions. Teachers and educators should make learners aware that the emotions they experience during studying do not necessarily represent valid indicators of their actual comprehension; instead, they need to carefully monitor and judge their own comprehension to efficiently regulate their learning. Moreover, interventions have been developed to promote learners' use of diagnostic cues. Specifically, comprehension tests usually assess learners' deeper understanding (i.e., their situation model) by requiring inferences or application of the textual information. Hence, comprehension-based cues, such as the ability to explain textual information, typically represent a valid judgment basis (e.g., Thiede et al., 2010). Interventions like concept mapping, rereading, setting appropriate test expectancies, and delayed summary writing, keywords listing, or diagram completion have been found to help learners use comprehension-based cues, thereby enhancing their metacomprehension accuracy (for recent overviews, see Griffin et al., 2019; Prinz et al., 2020b; Wiley et al., 2016). In addition, informing learners about the importance of and training them in providing accurate judgments can be effective methods (e.g., De Bruin et al., 2017; Händel et al., 2020; Roelle et al., 2017).

It is noteworthy that previous research suggests that the detrimental effects of negative-deactivating emotions such as hopelessness on cognitive processes (e.g., attention and motivation) are more consistent than the effects of negative-activating emotions such as anxiety. However, both activating and deactivating negative emotions typically have an adverse impact on learners' overall academic achievement (e.g., Goetz & Hall, 2013; Pekrun et al., 2007, 2017). Our findings indicate that the associations with learners' text comprehension, metacomprehension judgments and accuracy are also quite similar across various negative emotions – irrespective of whether they represent activating or deactivating ones.

The present study investigated how achievement emotions affect self-regulated learning from texts. Previously, Prinz et al. (2019) explored the impact of experimentally induced affect (i.e., positive, neutral, negative). It seems that the results on affect and achievement emotions are quite similar. Concerning predictions and their accuracy both positive affect and achievement emotions were related to higher and in turn more overconfident predictions, at least in tendency, compared with neutral or negative affect and achievement emotions that were associated with lower and accordingly more accurate or underconfident predictions. Concerning postdictions, affect had no impact, whereas positive achievement emotions were related to higher postdictions compared with neutral or negative achievement emotions. However, postdictions tended to be more accurate for learners with positive affect and achievement emotions but underconfident for learners with neutral or negative affect and achievement emotions. Hence, it seems that despite their varying object focus, both affect unrelated to learning as well as achievement emotions that specifically occur during learning are used as cues and influence the accuracy of comprehension judgments. Furthermore, in addition to the research on learning from texts cited above, the role of affect on monitoring accuracy has been investigated in the context of general-knowledge questions. Specifically, Sidi et al. (2018) found that undergraduates in a positive-induced affective state were more strongly overconfident in their knowledge than undergraduates in a neutral-induced affective state (negative affect was not examined). This outcome indicates that the impact of affect on monitoring accuracy is comparable for learning from text and answering general-knowledge questions. Nevertheless, in addition to examining different types of emotional states (i.e., affect and achievement emotions), future studies should

investigate to what extent the findings converge across different tasks (e.g., learning from texts, problem solving, reasoning, answering knowledge questions).

Limitations and future research

The present study contributes to an advanced understanding about the role of achievement emotions in self-regulated learning from texts. However, it is important to acknowledge limitations of the study and related directions for future research. First, we applied a correlational design in order to examine learners' naturally occurring achievement emotions. This design limits the causal conclusions that can be drawn from the study. Thus, longitudinal and experimental studies are needed to shed further light on the contribution of reading-related achievement emotions to comprehension and judgment processes. Second, the learners did not experience a very high degree of negative achievement emotions in this study. One reason might be that we did not examine a high-stakes setting. That is, although it was emphasized that the topic was generally important, the learners knew that their performance in the study would remain anonymous and have no impact on their grade. A high-stakes setting may amplify achievement emotions, particularly negative ones. Third, in the study, we considered a broad range of important achievement emotions that learners frequently experience during learning and are therefore covered in the Achievement Emotions Questionnaire (Pekrun et al., 2011). Nevertheless, there are further achievement emotions that can occur before, during, or after an academic task. For example, we did not include deactivating positive emotions, such as relief and relaxation, as they typically occur after a study or test situation is completed. It is an open question whether the observed effects hold true for emotions not assessed herein. Relatedly, the Achievement Emotions Questionnaire (Pekrun et al., 2011) provides scales for assessing three positive and five negative learning-related emotions. Hence, there is an asymmetry in the number of items measuring positive versus negative emotions. It is unclear whether this asymmetry could affect participants, for example, by priming negative emotions more strongly, thus influencing their response behavior. This methodological question might be addressed by future studies on achievement emotions. Fourth, we investigated state emotions, because learners might be particularly inclined to use them as cues due to their salience, and because state emotions are easier to modify than trait emotions. However, trait emotions are important to examine as well, because they are stable characteristics of learners and might therefore have a steady impact on their learning processes. Fifth, learners' academic standing might play a role for their emotional experiences as well as for their self-regulated learning processes. In fact, it has been shown that learners' academic achievement can influence their emotions (e.g., Pekrun et al., 2017) and judgments (e.g., Hacker et al., 2000). Hence, future research should additionally assess learners' academic performance to examine to what extent it relates to the achievement emotions they experience during reading and to subsequent judgments about their comprehension. Finally, to explain the effects of achievement emotions, we made theoretical assumptions about learners' cognitive processes (e.g., task-irrelevant thinking, cue use). In addition, we suggested that the same processes occur with activating and deactivating negative emotions. However, the actual mechanisms underlying the impact of the emotions are unclear. Therefore, future research should apply process measures. For instance, having participants thinking aloud while reading and providing judgments could reveal their underlying cognitive processes as well as the cues they use to make judgments.

Conclusion

The present study brought together two separate lines of research, that is, research on achievement emotions and research on self-regulated learning from texts. Enhancing the statistical power and external validity of the study, a large sample of adolescent learners in a regular classroom session was examined. The results indicate that achievement emotions are generally used as cues for making predictions and postdictions. However, achievement emotions do not necessarily represent diagnostic cues and can therefore lead to inaccurate predictions and postdictions. Consequently, instructional methods should be applied to aid learners in attaining more accurate metacomprehension and thus in self-regulated learning from texts.

Appendix A

Results on test-related achievement emotions

We used all seven available scales of the Achievement Emotions Questionnaire (Pekrun et al., 2011) to measure the emotions learners had experienced during testing, namely enjoyment (3 items), pride (2 items), hope (2 items), anxiety (7 items), anger (2 items), shame (5 items), and hopelessness (6 items). The participants were instructed to report how they felt while completing the test questions. They indicated their agreement with each item on a 5-point Likert scale ranging from 1 (*strongly disagree*) to 5 (*strongly agree*). To create the seven emotion scales, scores on the respective items were averaged. Moreover, composite scales for positive and negative achievement emotions were generated by averaging the scores on all items assessing positive and negative emotions, respectively. That is, the items on enjoyment, hope, and pride were merged to create the positive-emotions variable and the items on anger, anxiety, shame, and hopelessness were merged to create the negative emotions variable. While the scales for anger and hope exhibited a rather poor internal consistency, the internal consistency of the remaining scales was at least acceptable (see Table 5).

Table 5 Descriptive statistics for the test-related achievement emotions

Test-related achievement emotion	*M*	*SD*	Cronbach's α
Enjoyment	2.93	0.91	.82
Pride	2.81	1.01	.76
Hope	3.16	0.94	.62
Positive emotions	2.96	0.82	.87
Anxiety	1.49	0.59	.82
Anger	1.62	0.80	.51
Shame	1.60	0.70	.84
Hopelessness	1.57	0.70	.87
Negative emotions	1.55	0.55	.92

Table 6 Correlations among the test-related achievement emotions and dependent variables

Test-related achievement emotion	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1. Enjoyment	-													
2. Pride	.54**	-												
3. Hope	.61**	.65**	-											
4. Anxiety	-.01	.13*	.02	-										
5. Anger	-.29**	-.10†	-.26**	.27**	-									
6. Shame	-.22**	-.01	-.22**	.61**	.41**	-								
7. Hopelessness	-.41**	-.17*	-.42**	.44**	.59**	.71**	-							
8. Positive emotions	.87**	.83**	.85**	.05	-.27**	-.18**	-.40**	-						
9. Negative emotions	-.28**	-.05	-.26**	.77**	.60**	.86**	.84**	-.24**	-					
10. Text comprehension	.11*	-.02	.06	-.03	-.01	-.06	-.07	.06	-.06	-				
11. Prediction magnitude	.16*	.21**	.21**	-.05	-.03	-.14*	-.22**	.22**	-.15*	.16*	-			
12. Postdiction magnitude	.31**	.15*	.31**	-.18**	-.27**	-.34**	-.40**	.31**	-.38**	.25**	.48**	-		
13. Prediction accuracy	.01	.14*	.07	-.01	< -.01	-.03	-.08	.09	-.04	-.73**	.52**	.09†	-	
14. Postdiction accuracy	.11*	.10†	.16*	-.09	-.18**	-.17*	-.21**	.15*	-.20**	-.67**	.21**	.50**	.71**	-

*$p < .05$

**$p < .001$

†$p < .10$

Table 6 provides the Spearman correlations between the test-related achievement emotions and the dependent variables. Values of .01, .03, and .05 represent thresholds for small, medium, and large effects, respectively (Cohen, 1988).

Appendix B

Differences in the percentages of overconfident, underconfident, and accurate predictions and postdictions between the three emotion-profile groups

We investigated whether the three emotion-profile groups differed with regard to the percentages of overconfident, underconfident, and accurate judgments. Descriptive statistics are provided in Table 7.

Differences in the percentages of overconfident, underconfident, and accurate predictions

The overall effect on the percentage of overconfident predictions was only marginally significant, Welch's $F(2, 167.38) = 2.58$, $p = .079$, $\eta^2 = .02$. However, to examine differences between groups according to our hypothesis, we conducted planned orthogonal contrasts. The prediction-accuracy hypothesis suggested that a higher percentage of overconfident predictions should be found in groups that experience more positive and less negative emotions. This was tested with the following contrast weights. First contrast: positive group: 2, negative group: -1, neutral group: -1. Second contrast: positive group: 0, negative group: -1, neutral group: 1. In line with the prediction-accuracy hypothesis, the first contrast showed that participants in the positive group more often provided overconfident predictions than participants in the negative and neutral groups, $t(328,52) = 2.25$, $p = .025$, $\eta^2 = .02$. There was no significant difference between participants in the latter two groups, $t(151,52) = 0.13$, $p = .894$, $\eta^2 < .01$.

There were no significant overall effects concerning the percentages of underconfident, Welch's $F(2, 157.53) = 1.82$, $p = .165$, $\eta^2 = .01$, and accurate predictions, $F(2, 340) = 0.13$, $p = .876$, $\eta^2 < .01$.

Table 7 Percentages of overconfident, underconfident, and accurate predictions and postdictions by emotion-profile group

Variable	Positive group		Neutral group		Negative group		Overall sample	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Overconfident Predictions	46	50	35	48	34	48	41	49
Underconfident Predictions	25	44	35	48	35	48	30	46
Accurate Predictions	29	45	31	46	32	47	30	46
Overconfident Postdictions	28	45	19	40	14	34	23	42
Underconfident Postdictions	38	49	58	50	63	49	49	50
Accurate Postdictions	34	48	22	42	24	43	29	45

Differences in the percentages of overconfident, underconfident, and accurate postdictions

The percentage of overconfident postdictions significantly differed between groups, Welch's $F(2, 175.80) = 4.38$, $p = .014$, $\eta^2 = .02$. The postdiction-accuracy hypothesis suggested that a higher percentage of overconfident postdictions should be found in groups that experience more positive and less negative emotions. To examine the expected group differences, we conducted planned orthogonal contrasts as described for the percentage of overconfident predictions. In line with the postdiction-accuracy hypothesis, the first contrast showed that participants in the positive group more often provided overconfident postdictions than participants in the other groups, $t(321,89) = 2.59$, $p = .010$, $\eta^2 = .02$. However, there was no significant difference between participants in the negative group and the neutral group, $t(140,91) = 1.00$, $p = .318$, $\eta^2 < .01$.

There was a significant overall effect on the percentage of underconfident postdictions, $F(2, 340) = 9.61$, $p < .001$, $\eta^2 = .05$. According to the postdiction-accuracy hypothesis, a higher percentage of underconfident postdictions should be found in groups that experience less positive and more negative emotions. Thus, for this analysis, the contrast weights were as follows. First contrast: positive group: -2, negative group: 1, neutral group: 1. Second contrast: positive group: 0, negative group: 1, neutral group: -1. In support of the postdiction-accuracy hypothesis, the first contrast showed that participants in the positive group made underconfident postdictions less often than participants in the other groups, $t(340) = 4.29$, $p < .001$, $\eta^2 = .05$. However, participants in the negative group and the neutral group did not significantly differ from each other, $t(340) = 0.59$, $p = .554$, $\eta^2 < .01$.

The overall effect on the percentage of accurate postdictions was only marginally significant, Welch's $F(2, 172.73) = 2.63$, $p = .075$, $\eta^2 = .02$. Nevertheless, to examine the expected group differences, we conducted planned orthogonal contrasts. The postdiction-accuracy hypothesis indicates that the positive group ought to be the most accurate group and the negative group the least accurate group. Thus, for this analysis, the following contrast weights were used. First contrast: positive group: 2, negative group: -1, neutral group: -1. Second contrast: positive group: 0, negative group: -1, neutral group: 1. In line with the postdiction-accuracy hypothesis, the first contrast showed that participants in the positive group more often provided accurate postdictions than participants in the negative and neutral groups, $t(333,88) = 2.30$, $p = .022$, $\eta^2 = .02$. There was no significant difference between participants in the latter two groups, $t(153,23) = -0.21$, $p = .838$, $\eta^2 < .01$.

Author contributions Conceptualization: Anja Prinz-Weiß; Methodology: Anja Prinz-Weiß; Project administration: Anja Prinz-Weiß; Data collection: Laura Lukosiute, Mona Meyer, and Janina Riedel; Data curation: Laura Lukosiute, Mona Meyer, Anja Prinz-Weiß, and Janina Riedel; Formal Analysis: Anja Prinz-Weiß; Writing – original draft: Anja Prinz-Weiß; Writing – review & editing: Anja Prinz-Weiß.

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Declarations

Conflicts of interest The authors declare that they have no conflict of interest.

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