If You Don't Like It, You Won't Get It: Attitudes Toward Statistics Predict Text Comprehension and Metacomprehension Accuracy on Statistics Texts

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Abstract

Attitudes toward statistics influence the way students engage in learning statistics. This study examined how attitudes toward statistics were related to the comprehension of a statistics text and the accuracy with which learners judged their comprehension. Results showed that more negative attitudes were associated with lower performance on procedural comprehension questions, but not on conceptual comprehension questions. At the same time, more negative attitudes resulted in overestimations of procedural comprehension when making prospective and retrospective judgments of comprehension. To explain the findings, we draw on theoretical models that assume that learners use different types of cues to make comprehension judgments.

Keywords: attitudes toward statistics; learning; metacomprehension accuracy; judgment bias

Introduction

Many study programs include mandatory courses in statistics. However, the subject statistics often polarizes learners because they seem to be either in favor or against this subject. Such attitudes can dramatically impact learning because the more negative attitudes toward statistics are, the lower the performance in statistics usually is (Emmioğlu & Çapa-Aydın, 2011). Whether attitudes also impact metacognitive processes in learning, for example, when learners read a statistics text and judge their comprehension (i.e., metacomprehension accuracy; Griffin, Wiley, & Salas, 2013), is, however, an open question. Following the cue utilization approach (e.g., Koriat, 1997) as the theoretical framework for metacomprehension, attitudes might in fact misguide learners when they judge their comprehension. Thus, we examined the role of attitudes toward statistics for metacomprehension accuracy and text comprehension.

Attitudes Toward Statistics Impact Performance

Attitudes toward statistics are the disposition to view the domain of statistics, a specific topic in statistics (e.g., probability theory), or activities (e.g., performing statistical computations) with some degree of favor or disfavor (Zieffler et al., 2008). Learners typically have attitudes regarding statistics that, on average, range from being slightly negative (Budé et al., 2007; Zimprich, 2012) to slightly positive (Evans, 2007; Vanhoof et al., 2006). Many studies show that learners with more positive attitudes toward statistics perform higher in statistics than learners with more negative attitudes (Emmioğlu & Çapa-Aydın, 2011; Evans, 2007), partly because learners with more negative attitudes use fewer cognitive strategies when learning from statistics text (Budé et al., 2007; Kesici, Baloğlu, & Deniz, 2011). The positive relationship between attitudes and performance exists for both aspects of performance in statistics that are bi-directionally linked to each other (cf. Gal, 2002): the execution of statistical computations (i.e., procedural knowledge) and the knowledge about statistical concepts (i.e., conceptual knowledge; Evans, 2007).

Metacomprehension Accuracy

In addition to engaging in cognitive processes, successful learning from text requires learners to accurately monitor and judge their text comprehension. This metacognitive aspect of learning is called metacomprehension accuracy (Griffin et al., 2013). Learners are usually poor at accurately judging their comprehension because they often overestimate and, in some cases, underestimate their comprehension (e.g., Golke & Wittwer, 2017; Prinz, Golke, & Wittwer, 2018). Over- and underestimations can hamper self-regulated learning. For example, an overconfident learner is likely to quit studying prematurely which can result in underachievement (Dunlosky & Rawson, 2012).

Methodologically, metacomprehension accuracy is mirrored in the match between a comprehension judgment and actual performance on a comprehension test (Griffin, Jee, & Wiley, 2009). As comprehension judgments, research often uses prospective judgments but also retrospective judgments, both of which refer to the performance on a comprehension test. Prospective judgments are retrieved after reading a text but before answering test questions whereas retrospective judgments are made after having answered a set of test questions.

According to the cue utilization approach (e.g., Koriat, 1997) which is often used in metacomprehension research (e.g., Griffin et al., 2009), learners can use various cues for monitoring and judging their comprehension. The accuracy of the judgments depends on whether the cues utilized are

valid indicators of the comprehension that is measured by a comprehension test. When making prospective judgments, learners can use heuristic cues that are available whether or not a text has been read such as self-perceived skills and resources (e.g., ability, prior knowledge, interest). For example, a learner with a high self-perceived reading ability who draws on this self-perception would make a high comprehension judgment. In addition to heuristic cues, learners can base a comprehension judgment on cues that arise from processing a text and constructing a mental representation of the text (i.e., representation-based cues). Utilizing representation-based cues instead of heuristic cues normally results in more accurate judgments because representation-based cues more closely mirror the actual comprehension of a specific text. Moreover, learners who engage more deeply in text comprehension gain more valid representation-based cues than learners who process a text on a shallow level because deep processing provides a more complete picture of how well a text was understood. Consequently, a deeper text comprehension usually leads to more accurate judgments (Thiede et al., 2009).

When making retrospective judgments, learners can use additional cues that emerge from answering the test questions (e.g., number of unanswered questions, confidence in retrieved answers). These cues are normally strong indicators of comprehension (cf. Golke & Wittwer, 2017). Therefore, retrospective judgments are usually less overconfident or even rather accurate compared with prospective judgments (Pierce & Smith, 2001).

The Possible Role of Attitudes Toward Statistics in Metacomprehension Accuracy

Research has paid little attention to the role of attitudes (toward statistics) for metacomprehension accuracy so far. Following the cue utilization approach (Griffin et al., 2009; Koriat, 1997), attitudes might function as a heuristic cue when learners draw on their attitudes to form a judgment. In this case, more positive attitudes would lead to more optimistic judgments and more negative attitudes to more pessimistic judgments. Given the positive relationship between attitudes toward statistics and performance in statistics (Emmioğlu & Çapa-Aydın, 2011; Evans, 2007), heuristic judgments should be rather accurate. This is because learners with positive attitudes would provide high judgments and achieve a high performance while learners with negative attitudes would produce low judgments and achieve a low performance. Thus, when used as a heuristic cue, attitudes toward statistics would not be specifically related to the accuracy of judgments (higher and lower levels of attitudes related to rather accurate judgments) but positively associated with performance.

Alternatively, attitudes toward statistics could be indirectly related to metacomprehension accuracy if learners use representation-based cues to judge their comprehension of a statistics text. This is because attitudes toward statistics can influence the processing of a statistics text (Budé et al., 2007): Learners with more negative attitudes are less likely to engage in deep comprehension of a statistics text than learners with more positive attitudes. Given that shallow text comprehension provides less valid representation-based cues for judgments, learners with more negative attitudes toward statistics should arrive at more overconfident judgments than learners with more positive attitudes. In this case, learners with more negative attitudes are particularly handicapped because they would gain a low text comprehension and, due to their overestimations, abstain from further learning activities that could improve their understanding.

Present Study

We examined how attitudes toward statistics were related to the comprehension of a statistics text and to metacomprehension accuracy. In line with common views on statistical knowledge (Gal, 2002), the text comprehension test included conceptual and procedural comprehension questions. To assess metacomprehension accuracy, participants provided prospective and retrospective judgments. We tested the following hypotheses.

Hypothesis 1: Learners with more negative attitudes toward statistics perform lower on the conceptual and procedural comprehension questions than learners with more positive attitudes.

Hypothesis 2: Learners in general overestimate their conceptual and procedural comprehension for prospective judgments.

Hypothesis 3: Learners in general show no tendency towards overestimation when making retrospective judgments of conceptual and procedural comprehension.

Hypothesis 4: Regarding the role of attitudes toward statistics for metacomprehension accuracy, theory allows two possible, yet differing assumptions. 4a) When used as a heuristic cue, attitudes are not specifically related to the accuracy of prospective and retrospective judgments. 4b) Alternatively, when learners use representation-based cues for comprehension judgment, more negative attitudes result in more overoptimistic prospective and retrospective judgments, due to their negative impact on text comprehension, than more positive attitudes.

Hypothesis 5: The accuracy of retrospective judgments is, in addition to the possible role of learners' attitudes, influenced by learners' experience from answering the test question. Hence, learners who are overoptimistic on the correctness of their answers to the test questions produce more overconfident retrospective judgments.

Method

Sample

Participants were 29 undergraduate students in educational science from a German university who have been attending their first course in statistics for five weeks. Students participated as part of their regular course. In this study, we presented the students with a new topic in statistics (i.e.,

variation and variance). Participants' mean age was 23.03 years (SD = 4.93). The great majority (86%) were female.

Materials

The statistics text described the concepts of variation and variance including the formulas to calculate each measure. The text (293 words) was adapted from the German statistics textbook written by Holling and Gediga (2010).

We used two types of questions to assess comprehension of the statistics text: conceptual and procedural comprehension questions. The four conceptual questions addressed the understanding of critical attributes of the statistical concepts. Therefore, the answers to these questions were not explicitly provided in the text but had to be inferred. An example question is: *You calculate the variation in height of 15 people who differ in height. You had measured height in cm. If you calculate height in m, not in cm, how would variation in cm differ from variation in m?* All conceptual questions were presented in single-choice format with four answer alternatives.

The four procedural questions asked the students to apply information from the text to calculate a statistical measure (e.g., the variance). An example is: *You have a variable with the following values: 0, 0, 2, 2. Calculate the variance.* All procedural questions were open-format questions. We instructed participants to write down the solution and solution steps.

Instruments and Measures

Attitudes Toward Statistics We used the *Survey of Attitudes Toward Statistics* (Schau et al., 1995) that we had translated into German. The SATS contains 28 items. We presented the items on a 6-point Likert scale (1 = *completely disagree*, 6 = *completely agree*). A higher total score represents a more positive attitude. Internal consistency was very good, Cronbach's α = .89.

Due to limited access to our sample, we only had one session to conduct our study. Therefore, we administered the SATS at the end of this session, not at the beginning. Given that attitudes are stable (Zieffler et al., 2008), it should not make a difference whether the questionnaire is presented at the beginning or at the end of the session. Accordingly, a pilot study with 28 undergraduate students who answered the SATS at the beginning and the end of a session in a statistics course showed that the attitude scores did not significantly differ from each other, $t(27) = 1.59$, $p = .124$, $M_{begin} = 3.91$, $SD_{begin} = 0.58$, $M_{end} = 3.82$, $SD_{end} = 0.61$. Consequently, we administered the SATS at the end of the session in our main study so that the cognitively more challenging reading assignment and comprehension questions preceded the SATS.

Comprehension Judgments Prior to answering the comprehension questions, participants indicated how many questions they thought they would answer correctly (= prospective judgment). Additionally, after completing the comprehension questions, participants judged how many questions they thought they had answered correctly (= retrospective judgment). The judgments were made separately for the conceptual and procedural questions. We converted participants' judgments into percent values. Moreover, participants indicated for each comprehension question whether they were confident or unconfident that their answer was correct (= response confidence).

Judgment Bias As a measure of metacomprehension accuracy, we used the judgment bias. It is the signed difference between a participant's prospective or retrospective judgment of comprehension and actual performance on the comprehension questions. Hence, a participant who had a negative value of judgment bias had underestimated his/her comprehension whereas a participant with a positive value had overestimated comprehension (using percent values, –100 and +100 were the maximum under- and overestimation, respectively). The value of judgment bias was zero when a participant's judgment matched actual performance (i.e., accurate judgment).

Metacognitive Sensitivity To determine participants' accuracy in response confidence, we used the measure d', also known as metacognitive sensitivity (Fleming & Lau, 2014). It represents the ability to discriminate between correct and incorrect answers. Grounded on the signal detection theory, the measure is based on the hit rate (i.e., number of events when a reader provided a correct answer to a comprehension question and was confident that it was the correct answer, divided by total number of correct answers) and false alarm rate (i.e., number of events when a reader gave an incorrect answer but was confident that is was the correct solution, divided by the total number of incorrect answers). The measure d' is the difference between the standardized hit rate and the standardized false alarm rate. Therefore, a positive value of d' means that the hit rate is higher than the false alarm rate and, hence, reveals good sensitivity. A negative value (i.e., higher false alarm rate than hit rate) indicates poor sensitivity because the participant more often considered a false answer to be correct than a correct answer. A value of zero reflects a lack of discrimination between correct and incorrect responses.

Response Bias The measure c is a participant's tendency to accept or avoid false alarms [c = -0.5 * (standardized hit rate + standardized false alarm rate)]. A positive value of c means that the participant is cautious when giving confidence judgments on single comprehension questions in order to avoid false alarms. A negative value indicates a tendency to accept false alarms.

Procedure

We instructed participants to read the statistics text carefully to gain a complete understanding of the text which would be tested after reading. After reading the text, participants were informed about the details of the type and number of comprehension questions and asked to make prospective judgments on the conceptual and procedural questions. Afterwards, participants answered the conceptual questions and indicated their response confidence in each question. Subsequently, participants made their retrospective

judgments of the conceptual questions. Then they continued with the procedural questions for which they also indicated their response confidence. After having completed all procedural questions, participants made their retrospective judgments of these questions. Finally, participants provided information on demographic data and answered the SATS.

Scoring and Missing Data

We assigned 1 point to a correct answer and 0 points to an incorrect answer to the conceptual and procedural questions. The procedural questions were rated as correct when both the solution and solution steps were correct. To this end, two raters independently scored participants' answers to the procedural questions. There were four ratings per participant and 116 ratings for the total sample for each rater. Both raters agreed on 114 of the 116 ratings, which equaled a highly satisfying agreement of 98% (Cohen's $\kappa = .97$, 95% CI [.92, 1.00]).

One participant provided no prospective judgment. Thus, analyses concerning the prospective judgments were based on the data of 28 participants.

Results

Attitudes and Text Comprehension

Participants reported attitudes toward statistics that ranged from 2.61 to 4.75 points ($M = 3.75$, $SD = 0.55$) on the 6-point scale. Thus, participants differed from each other in having slightly negative to rather positive attitudes toward statistics. In line with hypothesis 1, we found that participants with a more positive attitude showed a higher procedural comprehension than participants with a more negative attitude, $r = .65$, $p < .001$ (see Table 1 for descriptive statistics). In contrast, participants' attitudes were not related to their conceptual comprehension, $r = -.01$, $p = .95$.

Judgment Bias

As Table 1 shows, participants varied in the extent to which they over- or underestimated their conceptual and procedural comprehension of the statistics text. Using *t*-tests against zero (which indicates a perfectly accurate judgment), results showed in line with hypothesis 2 that participants in general overestimated their conceptual comprehension when making prospective judgments, $t(27) = 3.95$, $p < .001$, Cohen's $d = 1.06$ (large effect). Regarding the prospective judgments of procedural comprehension, there was no general tendency towards over- or underestimation, $t(27) = 0.13$, $p = .897$, Cohen's $d = 0.04$ (small effect), which disconfirmed hypothesis 2.

Moreover, *t*-tests showed that the retrospective judgment bias did not significantly deviate from zero, neither for the conceptual, $t(28) = 1.46$, $p = .155$, Cohen's $d = 0.38$ (small effect), nor for the procedural comprehension, $t(28) = -0.29$, $p = .774$, Cohen's $d = -0.08$ (medium effect). This finding was in line with hypothesis 3.

Table 1: Mean percent performance and judgment bias (with standard deviation) for the comprehension questions.

		Bias	
	Performance	Pro-spective	Retro-spective
Conceptual questions	39.66 (27.97)	+24.11 (32.26)	+9.48 (34.98)
Procedural questions	45.69 (42.82)	+0.89 (36.31)	–1.72 (32.00)

Relations Between Attitudes and Judgment Bias

To statistically test hypotheses 4 and 5, we used linear regression analyses. For the prospective judgments, we conducted two simple regression analyses with attitudes as predictor and judgment bias of conceptual and procedural comprehension, respectively, as criterion. As Table 2 shows, attitudes were not significantly related to judgment bias of conceptual comprehension. Attitudes were, however, a significant and negative predictor of the judgment bias of procedural comprehension. Thus, participants with more negative attitudes toward statistics more strongly overestimated their procedural comprehension of the statistics text when making prospective judgments, which supported hypothesis 4b.

Table 2: Simple linear regression analyses predicting bias of prospective judgments of comprehension.

Predictor	*B*	SE *B*	*t*(26)	*p*
Conceptual questions				
Constant	-0.23	0.42	-0.56	.582
Attitudes	1.27	0.11	1.15	.262
Procedural questions				
Constant	1.17	0.42	2.76	.011
Attitudes	-0.31	0.11	-2.77	.010

Note. Conceptual questions: $R^2 = .05$, $F(1, 26) = 1.31$, $p = .262$, procedural questions: $R^2 = .23$, $F(1, 26) = 7.65$, $p = .010$.

Regarding the retrospective judgments, we performed two multiple regression analyses using attitudes and, in addition, metacognitive sensitivity and response bias as predictors and judgment bias of conceptual and procedural comprehension, respectively, as criterion. As Table 3 shows, attitudes toward statistics were not significantly related to the bias of the retrospective judgments of the conceptual comprehension. Yet, participants' metacognitive sensitivity and response bias were significantly and negatively associated with this bias measure (confirming hypothesis 5). Thus, participants who were less accurate when judging the correctness of their responses to the conceptual questions (i.e., lower metacognitive sensitivity and response bias) were also more overconfident on the retrospective judgments of the conceptual comprehension.

Regarding the bias of the retrospective judgments of the procedural comprehension, analyses revealed that response bias (confirming hypothesis 5) and, although to a marginal extent, attitudes (supporting hypothesis 4b) were significant and negative predictors. This result suggests that not only participants who were less accurate when judging the correctness of their responses to the procedural questions but also those who had more negative attitudes toward statistics arrived at more overconfident retrospective judgments of the procedural questions than those participants who more accurately indicated response correctness and who had more positive attitudes.

Table 3: Multiple linear regression analyses predicting bias of retrospective judgments of comprehension.

Predictor	*B*	SE *B*	*t*(25)	*p*
Conceptual questions				
Constant	-0.54	0.40	-1.34	.192
Attitudes	0.17	0.11	1.59	.124
Sensitivity (*d*')	-0.08	0.04	-2.29	.031
Response bias	-0.20	0.09	-2.28	.031
Procedural questions				
Constant	0.75	0.44	1.72	.098
Attitudes	-0.21	0.12	-1.77	.089
Sensitivity (*d*')	-0.08	0.06	-1.39	.176
Response bias	-0.22	0.07	-3.38	.002

Note. Conceptual questions: $R^2 = .43$, $F(3, 25) = 6.28$, $p = .003$, procedural questions: $R^2 = .44$, $F(3, 25) = 6.54$, $p = .002$.

Discussion

We aimed to expand the understanding of how attitudes toward statistics are related to learning statistics by examining the role of attitudes for comprehension and metacomprehension accuracy. Regarding the results on text comprehension, we found a strong relationship between attitudes and procedural knowledge, which is in line with previous research (Emmioğlu & Çapa-Aydın, 2011; Evans, 2007; Vanhoof et al., 2006): Participants with more positive attitudes acquired more procedural knowledge than participants with more negative attitudes. In contrast to our expectations, the results revealed no substantial relationship between attitudes and conceptual comprehension. A possible explanation for the latter finding is that, when reading the statistics text, participants might have focused on gathering information to perform statistical computations (i.e., procedural comprehension) instead of understanding the underlying concepts.

Moreover, when participants focused mainly on the procedural information and not on the conceptual information in the text, this could also explain why participants overestimated their conceptual comprehension more strongly than their procedural comprehension. Learners who mainly processed the procedural text information (e.g., how to calculate variance) would have obtained an adequate overview of their (lack of) understanding. In contrast, learners would have been less able to judge their conceptual understanding because they would not have paid enough attention to this specific information in the text, which results in illusions of understanding. In line with this finding, overestimations of comprehension are commonly found in different learning domains (Thiede et al., 2009).

In general, participants varied strongly in the extent to which they over- or underestimated their comprehension. In case of the procedural comprehension, this variance seems to partially result from participants' attitudes toward statistics. More concretely, we found that more negative attitudes toward statistics were associated with more overestimation. This negative relationship suggests that attitudes impacted text comprehension and that participants utilized the resulting representation-based cues rather than heuristic cues (cf. Griffin et al., 2009) to judge their comprehension of the procedural information in the text. Accordingly, it can be assumed that more negative attitudes resulted in a surface level of text processing and, thus, in a more shallow text representation whereas more positive attitudes led to a more active text processing and, hence, to a deeper text representation (cf. Budé et al., 2007; Kesici et al., 2011). As a consequence of using a more shallow text representation as a basis for judging comprehension, participants with more negative attitudes were more likely to overestimate their procedural comprehension than participants with more positive attitudes.

With respect to conceptual comprehension, we found, however, no substantial relationship between attitudes and the bias of prospective and retrospective judgments. This finding is likely to result from the fact that attitudes were not related to the performance on the conceptual comprehension questions.

Despite the interesting results obtained in this study, there are also some limitations. As we conducted this study within a regular statistics course, the sample size was rather small. Furthermore, we used only one statistics text. Therefore, to examine the generalizability of our findings, further studies need to include multiple texts and a larger sample. Moreover, the order of the conceptual and procedural questions was fixed. To gain further insight into possible interdependencies of judgment accuracy of different types of comprehension questions, studies should vary the order of presentation of conceptual and procedural questions. Finally, due to the correlational nature of the study, causal interpretations are limited. Thus, even though it is plausible to assume that attitudes causally affected metacomprehension accuracy, the exact nature of this relationship should be examined in future research using longitudinal or experimental designs.

Conclusions

This study has theoretical and practical implications. As a primary theoretical implication, this study suggests that attitudes pertain to a learner's individual characteristics, such as domain knowledge (cf. Griffin et al., 2009), that can

influence metacomprehension accuracy. Therefore, attitudes should be considered as a relevant factor for learning domains or texts that trigger learners' attitudes. Regarding the practical implications, the key finding of this study is that learners with more negative attitudes are more likely to overestimate their comprehension when reading statistics text than learners with more positive attitudes. Given that overestimations discourage further reading activities (Griffin et al., 2013), teachers in statistics should assist their students, for example, by prompting them to use reading strategies that enhance the chances of a thorough understanding of statistics texts.

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