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ABSTRACT

A knowledge monitoring assessment (KMA) was developed and evaluated. The KMA, which evaluates how well students distinguish between what they know and do not know by comparing their knowledge estimates to test performance, is partially performance based and may be group or computer administered and objectively scored. Participants were 462 academically gifted high school students in a summer enrichment program. Mathematical and verbal analogy KMAs were developed. Results confirm prior findings that the KMA has significant but moderate relationships with scholastic aptitude, and that these relationships are somewhat higher than those that study skills and metacognitive self-report scales have with scholastic aptitude. Results also suggest that the KMA has low relationships with self-report measures of metacognition and study skills, which are highly related to one another. Results do indicate that knowledge monitoring has significant relationship with school grades, and that accurate monitoring is an important variable in school learning. Evidence supports the construct validity of the KMA and its usefulness in the study of metacognition. (Contains 5 tables and 24 references.) (SLD)

Towards a Performance Based Measure of Metacognitive Knowledge Monitoring: Relationships with Self-Reports and Behavior Ratings

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Metacognition is one of the most actively investigated cognitive processes in contemporary psychological research. Despite that intense research activity the assessment of metacognition has turned out to be a difficult problem for several reasons. First, metacognition, defined as the ability to monitor, evaluate, and make plans for one's learning (Flavell, 1979; Brown 1980), is an executive level construct and the assessment of such complex constructs can be expected to be difficult. Second, metacognition has been most actively studied in experimental settings in developmental psychology, human learning, and instructional research, fields with different aims and methodologies than found in psychometric contexts. Finally, metacognition is a multifaceted construct, which may be divided (Pintrich, Wolters, & Baxter, in press) into three components: knowledge about metacognition, monitoring learning processes, and control of those processes. Therefore no single measure is likely to be an adequate assessment of the whole construct.

The purpose of this paper is to extend prior research on a measure of the knowledge monitoring component of metacognition which is partially performance based, and may be group or computer administered and objectively scored. The knowledge monitoring assessment (KMA) evaluates how well students distinguish between what they know and do not know by obtaining knowledge estimates and then comparing them to subsequent test performance. The discrepancy between estimates and performance is taken as the index of knowledge monitoring accuracy. A program of research (Tobias & Everson, in press; Tobias & Everson, 1998; Everson & Tobias, 1998; Tobias, Everson, & Laitusis, 1997, S. Tobias, Everson, & L. Tobias, 1997), some 19 studies to date, has suggested that this is a useful approach to the assessment of metacognitive knowledge monitoring. The present investigation extends this research program to the domain of verbal analogies which has not previously been investigated, and to a different sample than previously used- an academically talented population of secondary school students. Finally, inter-relationships between the KMA, scholastic assessment, self reports of study skills and metacognition, and teacher ratings of metacognition will also be examined.

Summary of Prior KMA Research Results

Research has shown that the KMA is highly related to reading achievement among college (Tobias, Hartman, Everson, & Gourgey, 1991; Everson, Smodlaka, & Tobias, 1994) and elementary school students (Fajar, Santos, & Tobias, 1996). Results have also shown (Everson & Tobias, 1998) moderate relationships between the KMA and prior, as well as future college grades. In view of the poor reliability of grades, among a number of other difficulties in using grade point average as a criterion (Tobias & Everson, in press), moderate relationships are the maximum that may be expected in such research. The KMA was also found (Tobias & Everson, in press) to be related to vocational high school students' grade point averages. As expected, secondary school students diagnosed as learning disabled or as having attention deficit disorders were significantly less accurate knowledge monitors than students without special needs (Tobias & Everson, in press). Similarly, high school dropouts were found (Gerrity & Tobias, 1996) to be less accurate knowledge monitors than continuing students.

It was expected that affective states which enhanced cognitive performance would increase monitoring accuracy, whereas those which tended to interfere with such performance would interfere with monitoring accuracy. These predictions were confirmed in a number of studies. Students' interest was found (Tobias, 1995) to enhance monitoring accuracy, whereas test anxiety (Everson, Smodlaka, & Tobias, 1994) as well as mathematics anxiety (Tobias & Everson, in press) were found to have negative relationships with knowledge monitoring.

The KMA has also been extended to mathematics by asking students to estimate whether they could solve questions involving computation or word problems, and then having them actually solve the problems (Tobias & Everson, 1995). That research indicated substantial relationships between the KMA and achievement in mathematics. Furthermore, it was expected that knowledge monitoring, like other cognitive abilities was expected to increase with age (Brown, 1980; Brown, A. L., Bransford, J. D., Ferrara, R. A., & Campione, 1983), and findings (Tobias & Everson, 1995) have confirmed increases in both mathematics achievement and knowledge monitoring accuracy from fourth to sixth grade. Positive relationships were obtained between the KMA and measures of ability used in the military (S.Tobias, Everson, & L. Tobias, 1997), and measures of learning in a course dealing with oceanography. Another study (Tobias & Everson, 1998) found significant relationships between the KMA and the analytic component of Sternberg's (1988) triarchic intelligence measures.

Seignon and Tobias (1996) reasoned that since accurate knowledge monitors had a good idea of what they knew and did not know they ought to be able to supply their own feedback regarding correctness of responses (Butler & Winne, 1995) and would rely less on external feedback than those less accurate. Elementary school students read a series of paragraphs ending in a question. After answering the question students were free to check on the correctness of their responses by lifting a tab covering the answer. As expected, a strong negative relationship (r=-.84) between accuracy on the KMA and amount of external feedback taken was found indicating that accurate knowledge monitors were more likely to supply their own internal verification and, therefore, required less external feedback than their less accurate peers. The KMA was also found to be related to strategic help seeking. In one study (Romero & Tobias, 1996) accurate knowledge monitors were found to seek more help on vocabulary words they estimated not knowing than less accurate monitors. That finding was substantially replicated in the domain of mathematics (Tobias & Everson, 1998).

Low relationships were found in prior research (Tobias & Everson, 1998) between the KMA and measures of study skills such as the Learning and Study Strategies Inventory (Weinstein, Palmer & Schulte, 1987) and the Motivated Strategies for Learning Questionnaire (Pintrich, Smith, Garcia & McKeachie, 1991). This question was re-examined in this study with a larger sample so that a reliable factor structure of the study skills questionnaires and self reports of metacognition could be obtained to examine that relationship more rigorously. Finally, none of the prior investigations had examined relationships between the KMA and self reports of metacognitive monitoring, nor between the KMA and behavioral ratings of metacognition. Therefore, these questions were also examined in this study.

Participants

A total of 462 students (214 female) participated in this study. Participants were from an academically gifted population ranging in grade from 9 through 11 and were attending a voluntary summer enrichment program conducted by the Institute for the Academic Advancement of Youth on a campus at a private college in Pennsylvania.

Method

In this study a number of assessments were administered to participants, and their scores related to scholastic assessment test (SAT) scores obtained from the files.

Materials

Two KMAs were developed for this study. A mathematical version consisted of 25 math problems, requiring a multiple choice response, drawn from prior versions of the SAT and SAT-II, a test for talented students in mathematics. A verbal analogies version consisted of a series of 30 verbal analogies, also in multiple choice format, adapted from prior versions of the PSAT/NMSQT.

Students also responded to these two questionnaires: 1) The Learning and Study Strategies Inventory (LASSI; Weinstein, Palmer & Schulte, 1987) a multiple choice scale consisting of 76 items examining students about the study strategies used while working on learning materials. The LASSI yielded 10 subscale scores. 2) The Metacognitive Awareness Inventory (MAI; Schraw & Dennison, 1994), a multiple choice 52 item instrument asking students questions presumed to deal with the metacognitive monitoring activities. The MAI yields eight subscale scores.

A seven item behavior rating scale was developed asking teachers to rate students regarding their planning, metacognitive monitoring, and awareness of evaluation outcomes.

Procedures

Students were initially given the LASSI (Weinstein, Palmer & Schulte, 1987). After approximately 30 minutes they were asked to stop and, those who had not completed the LASSI were told to complete the questionnaire later. The verbal analogies KMA was presented next and displayed one item at a time on a large screen projected on a "Performa" computer projection device controlled by a PowerPoint program. Each item was projected for eight seconds and participants checked, on a scoring sheet, whether they could or could not solve the analogy. Students were instructed not to solve the problem but merely to estimate whether they could solve it given a reasonable amount of time. The same procedure was followed for KMA math problems which were each projected for 20 seconds. Again, the students estimated whether they could solve the problem given enough time. Students then received booklets containing the same verbal analogies and math problems and asked to solve them by picking the correct answer from one of five choices. The MAI (Schraw & Dennison, 1994) was administered next and students' teachers were asked to complete the behavior rating scale on each student. Finally, data on students' scholastic SAT mathematics and verbal scores were obtained from program files.

Results and Discussion

The KMA generates the following four scores: Items students indicated that they could solve and 1) solved correctly, or 2) incorrectly. Or items they indicated that they could not solve and 3) did solve correctly, 4) or incorrectly. The hamann coefficient (Romesburg, 1984; Schraw, 1995) was then computed as a measure of knowledge monitoring accuracy. Hamann coefficients range from –1 to 1, where 1 indicates perfect knowledge monitoring and 0 indicates chance performance. A negative coefficient represents some level of bias (either over confidence or under confidence). Means and standard deviations for the hamann coefficients and SAT scores appear in Table 1.

Insert Table 1 here

Factor analyses were then computed on the LASSI, MAI, and the teacher rating scales. As recommended by Gorsuch (1983), scores on the 10 LASSI subscales were submitted to a principle components extraction procedure, and the two factors with Eigen values above unity submitted to varimax rotation. This factor structure was quite similar to that obtained previously (Everson, et al., 1997). The results of the present factor analysis, together with means and standard deviations for each subscale are shown in Table 2.

Insert Table 2 here

It seems that Factor I can best be interpreted as consisting of relatively general strategies used when students feel they are evaluated, whereas Factor II seems to consist of more specific learning strategies. A similar factor analysis was performed on the MAI (Schraw & Dennison, 1994) using scores on the eight subscales of which the instrument was presumed to consist as input The results, shown in Table 3, yielded only one factor with eigenvalues above 1.0,

Insert Table 3 here

suggesting a general metacognitive monitoring factor. Finally, a factor analysis of the teacher's student rating instrument was performed entering the rater's responses to each item which also yielded one factor. The factor scores from these analyses were used in subsequent computations examining the correlations between KMAs, self reports and behavioral ratings; these results, as well as the means and standard deviations, are shown in Table 4.

Insert Table 4 about here

A data set with a large number of subjects, such as this one, yields many significant relationships of relatively low magnitude. In order to make these data more interpretable, the discussion of the results will be organized into several sections: 1) Results dealing with the teacher rating scale, 2) Relationships with scholastic aptitude, 3) KMA relationships with self report measures, and 4) relationships among the self-report measures.

Teacher Rating Scale

The behavioral rating scale teachers completed about the students contributed little new information for a number of reasons. First, most teachers were reluctant to fill out the scale; data for only about 170 students out of a sample of 462 were completed. This reluctance was partially attributable to the teachers' feeling that students were participating in a voluntary enrichment program which did not use objective outcome measures; therefore they felt that it was not in keeping with program objectives to rate students on a behavior rating scale. Second, those teachers who did rate students were reluctant to assign ratings which were other than highly positive. The mean ratings, on a four point rating scale, ranged from a low of 3.14 to a high of 3.44. Clearly, there was little variability in the ratings. Finally, when teacher rating data were added to the regression analyses to be described below, the results were not materially altered. For these reasons, teacher rating data will not be used in the succeeding analyses.

Relationships with Scholastic Aptitude

It seems reasonable to expect positive relationships between knowledge monitoring ability and scholastic aptitude. Students who can accurately differentiate between what they know and don't know should have higher scholastic aptitude because they have a clear advantage in learning new material, since they can concentrate on unknown materials and skim over or ignore known content. Prior research has confirmed that reasoning and shown that accurate monitors were more strategic in seeking help on both vocabulary and mathematical problems (Romero &Tobias, 1996; Tobias & Everson, 1998) than their less accurate peers. The purpose of the present analyses was to examine the relative contributions of the KMA and the self report measures of study skill and metacognitive monitoring to scholastic aptitude.

A regression analysis used the enter procedure, in which all variables were forced into the equation, with the SAT mathematical score as the dependent variable and the two KMAs, the two LASSI factors and the MAI factor as the independent variable. A multiple correlation of .51 (r^2=.26, F (5,444)=31.2, p<.001) was found; the Beta weights (see Table 5) for this equation indicated

Insert Table 5 about here

that only the hamann coefficient for the math KMA contributed significantly to the prediction of math SAT. Clearly, monitoring accuracy in mathematics was more highly related to math aptitude than any of the other variables, a result confirmed by examining the correlations in Table 4.

An identical regression analysis was computed with the SAT verbal score as the dependent variable, and yielded a multiple correlation of .33 (r^2=.11, F(5,444)=10.79, p<.001). Table 5 also indicates that, as expected, the hamann coefficients for the verbal analogies KMA contributed the greatest amount of variance to this equation, followed by the hamann for the math items and by the MAI factor. These results indicate that the relationships of all variables with the verbal score on the SAT were more moderate than with the SAT math score. Again as expected the KMA verbal analogies contributed most significantly to the prediction of the SAT verbal score, followed by the KMA math hamann, and the general monitoring factor of the MAI. Clearly, knowledge monitoring accuracy was significantly related to the SAT Verbal score, though general monitoring ability, as reflected by the MAI, also contributed to that relationship.

Relationships Among KMA, Monitoring and Study Skills Self Reports

The next question addressed was the relationship between students' knowledge monitoring accuracy, determined by the KMA, and self report measures of metacognitive activity. In a prior study (Everson, Tobias & Laitusis, 1997) correlations between the KMA and scores on the LASSI scales were found to be low, often non-significant, and sometimes negative. These unexpected findings could be attributed to the fact that the LASSI does not have a specific scale assessing metacognition. A subsequent study (Tobias &

Everson, 1998) found similarly low relationships between KMAs based on vocabulary and math items and the LASSI. That investigation used a sample of 120 students and also found two LASSI factors, somewhat similar to those found in this study. In general, as Table 4 indicates, correlations between the LASSI factors and the KMAs were again found to be low. Regression analysis with the first LASSI factor as the dependent variable and both KMAs as the independent variable yielded a multiple correlation of .24 (r^2= .06, $F(2,456)= 14.44$, $p<.001$). An identical analysis with the second LASSI factor found a correlation of .21 (r^2= 04, $F(2,456)= 10.35$, $p<.001$). A similar regression analysis with MAI factor as dependent and the two KMAs as independent variables found a multiple correlation of .12 (r^2= 01, $F(2,447)=3.19$, $p<.05$). These results indicate that while there was some low, but significant, relationship between the knowledge monitoring assessments and self reports of study skills and metacognitive monitoring these measures share little common variance.

Another regression analysis related the two LASSI factors to the single MAI factor and found a multiple correlation of .61 (r^2= .37, $F(2,448)=130.48$, $p<.001$). Clearly, the LASSI and MAI seem to measure something very similar, whereas the KMAs seem to have considerable unique variance.

General Discussion

The results confirm prior findings that the KMA has significant but moderate relationships with scholastic aptitude, and that these relationships are somewhat higher than those study skills and metacognitive self report scales have with scholastic aptitude. The results also continue to indicate that the KMA has low relationships with self report measures of metacognition and study skills, which are highly related to one another. Finally, it was disappointing that the teacher rating scale was completed by few of the instructors and failed to discriminate among students. Clearly, it would have been desirable to be able to relate the different measures used in this research to ratings of students' learning in real school settings. A suggestion for further research is to use such scales in contexts in which students are routinely evaluated, and where the student population is more heterogeneous in terms of scholastic ability than was the case in this study. Such research would be more informative about the relationships between metacognitive evaluation instruments and students' school learning.

The results of this study, together with prior findings (Everson & Tobias, 1998; Tobias & Everson, in press) indicating that knowledge monitoring had significant relationship with school grades, continue to indicate that accurate monitoring is an important variable in school learning. Perhaps the moderate relationships between the mathematical SAT and the KMA in that domain, as well as the lower relationships between the verbal analogies KMA and the verbal SAT are partially attributable to the homogeneity of the sample. These relationships would probably have been higher if students with a wider range of academic aptitude had been used. However, it should be noted that despite the homogeneity of the sample in terms of academic ability, there was surprising variability with respect to knowledge monitoring accuracy. As Table 1 indicates, the ratio of the standard deviations divided by the means is only . 15 and .13 for the SAT Verbal and Math respectively, whereas it is a huge .53 and .67 for the verbal analogies and math hamann values indicating that variability with respect knowledge monitoring accuracy even in this homogeneous sample is substantial. It would be interesting to investigate whether even such academically talented samples can be differentiated from one another in terms of knowledge monitoring accuracy. Furthermore, it would also be useful to determine if the variability in knowledge monitoring accuracy is related to other variables of importance in school learning.

In future research, it would be worthwhile to study the relationships between student's strategic help seeking, using procedures such as those employed in prior studies with the KMA (Romero & Tobias, 1996; Tobias & Everson, 1998), and their school learning, scholastic aptitude, self reports of study skills or metacognition. Perhaps the variability of monitoring accuracy described above might be related to students' monitoring accuracy. Pursuing such research would do a great deal to relate knowledge monitoring to school learning for academically talented students such as those used in this study , as well as for a more heterogeneous sample of students, and help to specify some of the processes by which metacognition improves school learning. Unfortunately, time constraints made it impossible to include such measures in this study.

The low relationships between the KMA and self reports could be attributable to a number of factors. Unlike self report measures the KMA does not ask students to report on their study skills or cognitive processes, hence the differences in the types of responses required by the different assessment techniques may contribute to the low relationships. The fact that the two self report measures used in this study were substantially related to one another, while their relationships to the KMA were relatively low strengthens that possibility. It has been suggested (Gerrity & Tobias, 1996; Tobias & Everson, in press) that the KMA may be more resistant to students' attempts to present themselves in a more positive light than self report measures. That could be investigated directly by using varying instructions to different student groups and determining whether the KMAs or the self reports change more dramatically.

One of the questions arising in KMA research has been the possible confounding of monitoring accuracy and knowledge. In this study, and in many of the preceding ones in this research program, 64% of the responses to the KMA verbal analogies consisted of students' estimates that they could solve a problem and then passed that item on the test, and 67% of the responses to the mathematics items fell into that category. Such a preponderance of responses in that category raises the possibility that knowledge and accuracy are confounded, even though the hamann coefficient examines only the discrepancy between estimates and test performance. Future research might guard against this possibility in two ways. First, by including up to 25% insoluble problems which accurate students would have to estimate not being able to solve and thus reduce the preponderance of responses in the can solve category. Second, problems could be included in the test about which students were not asked to make any estimates. The score on these items could be an independent source of data regarding students' knowledge, and then used as a covariate in succeeding statistical analyses, reducing the possible confounding of knowledge and monitoring accuracy.

The results provide continuing evidence both for the construct validity of the KMA, and for its usefulness in the study of metacognition. The results demonstrate considerable generality of the KMA over a range of content, and over different samples. Vocabulary based KMAs have been used in 14 studies using eight different samples of vocabulary items; another vocabulary sample used words drawn from the domain of oceanography. KMAs using five different samples of mathematical problems were used in five studies, and the present study extended the content domains investigated to verbal analogies. Generality over different samples of participants was also demonstrated. College students participated in eight studies, navy trainees in one, and four studies used high school students (regular, vocational, dropouts, as well as students diagnosed as LD and ADHD). The present study consisted largely of junior high school students (84% of the sample), and elementary school students were used in another five investigations. Clearly then, the procedure may be useful in studies of metacognitive monitoring using a variety of content domains, and over a wide range of student samples.

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Table 1. Descriptive Statistics for Verbal Analogy Hamann, Math Hamann, SAT-Verbal, and SAT-Math.

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
Analogy Hamann	459	-.27	1.00	.447	.236
Math Hamann	459	-.52	1.00	.439	.295
SAT Verbal Score	462	270	760	521.82	80.49
SAT Math Score	462	300	800	582.36	78.68
Valid N (listwise)	459				

Table 2. LASSI Means, Standard Deviations, and Rotated Factor Loadings.

Descriptive Statistics				
Subscale	Mean	Std Dev	Factor 1	Factor 2
Attitude	31.73	5.40	**0.695**	0.413
Motivation	32.67	6.26	**0.674**	0.464
Anxiety	30.18	6.44	**0.762**	-0.319
Concentration	27.32	6.64	**0.644**	0.481
Select Main Ideas	19.49	3.52	**0.751**	0.211
Test Taking Strategies	32.50	5.52	**0.915**	0.004
Time Management	21.44	5.44	0.373	**0.611**
Info Processing	25.90	6.00	0.260	**0.675**
Study Aids	22.79	6.17	-0.133	**0.859**
Self Testing	24.59	6.16	0.067	**0.892**
N = 462				

Table 3. Metacognitive Awareness Inventory (MAI) means, standard deviations, and Factor Loadings.

Descriptives			Unrotated Factor Matrix
Subscale	Mean	Std Dev	Factor Loadings
Monitoring	24.00	4.56	0.878
Procedural Knowledge	15.08	2.74	0.833
Planning	23.63	4.90	0.841
Declarative Knowledge	31.32	4.68	0.760
Evaluation	20.18	3.94	0.815
Information Management	32.12	5.80	0.871
Conditional Knowledge	19.48	2.98	0.832
Debugging	19.57	3.31	0.783
N = 451			

Table 4. Correlations (N = 172 – 462) Among KMAs, SATs, LASSI and MAI Factors, and Teacher Ratings.

	Analogy KMA	Math KMA	SAT Verbal	SAT Math	Factor 1 LASSI	Factor 2 LASSI	MAI Factor	Teacher Rating
Analogy KMA	1.000	.321**	.291**	.150**	.186**	-.202**	.012	.070
Math KMA	.321**	1.000	-.010	.502**	.209**	-.112	.116	.143
SAT VERBAL	.291**	-.010	1.000	.139*	.059	-.104	-.107	-.078
SAT MATH	.150**	.502**	.139*	1.000	.075	-.103	.011	.004
Factor 1 LASSI	.186**	.209**	.059	.075	1.000	.000	.252**	.184
Factor 2 LASSI	-.202**	-.112	-.104	-.103	.000	1.000	.555**	.067
MAI Factor	.012	.116	-.107	.011	.252**	.555**	1.000	.124
Teacher rating	.070	.143	-.078	.004	.184	.067	.124	1.000

** Correlation is significant at the .001 level (2 tailed)
* Correlation is significant at the .01 level (2 tailed)

Table 5. Regression Beta weights reported for the prediction of SAT Math and Verbal.

Dependant Variable = SAT Math			
Variable	Beta	T	Sig T
KMA Math	0.5118	11.651	.000
LASSI Factor 2	-0.0419	-0.821	.412
MAI Factor	-0.0206	-0.396	.692
LASSI Factor 1	-0.0152	-0.349	.727
KMA Analogy	-0.0129	-0.294	.768
(Constant)		66.239	.000
Dependant Variable = SAT Verbal			
Variable	Beta	T	Sig T
KMA Analogy	0.3185	6.599	.000
KMA Math	-0.1054	-2.187	.029
MAI Factor	-0.1192	-2.087	.037
LASSI Factor 1	0.0499	1.046	.296
LASSI Factor 2	0.0130	0.233	.816
(Constant)		55.133	.000

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