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The role of interference in metacognitive monitoring

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THE ROLE OF INTERFERENCE IN METACOGNITIVE MONITORING

by

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ABSTRACT

Recent advancements in neuropsychology have initiated theoretical advancements in cognitive psychology, particularly concerning the constructs of interference and metacognition. These constructs share similar cognitive functioning and this study investigated the relationship between them. It was expected that students with higher monitoring ability would demonstrate lower susceptibility to interference. Students from undergraduate Educational Psychology classes were administered three tests: two measures of interference, and one measure of metacognitive monitoring ability. Variables from the Wisconsin Card Sort Test (WCST) and the Stroop Color and Word Test (SCWT) measured susceptibility to interference. A monitoring task applied to a math aptitude test was used to measure monitoring ability. Pearson-product correlations showed no relationship among the interference measures and monitoring ability. Furthermore, there was no relationship among the interference component scores and monitoring ability. The results of this study are also inconsistent with previous research concerning monitoring and math score prediction. Results showed no difference between the monitoring and non-monitoring groups in ability to predict math scores.

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Chapter 1

Introduction

Recent advances in neuropsychology have implications in cognitive psychology. The human brain has regions of very specific functioning and by studying patients with brain injury in a specific region we may gain insight into the separate components of the cognitive system in those without brain injury. Interference and metacognition are both processes of human cognition; interference involves fundamental processes, whereas, metacognition involves higher cognitive processes. Although these constructs involve some of the same information processing procedures, the relationship between them has not been widely examined.

A variety of cognitive processes are interference sensitive such as attention, memory, comprehension, and reasoning (Dempster, 1985). These same processes are involved in metacognitive monitoring (Corkill and Koshida, 1993; Flavell, 1981, 1985; Brown, 1987). Advancements in interference theory (neointerference), as well as metacognitive theory concentrate on the role of interference in complex thinking and reasoning processes.

Interference

Interference is a key component of our daily cognitive functioning. We are constantly receiving infinite amounts of stimuli which must be attended; stimuli may be selected for further processing or ignored. This selection skill is a key to effective cognitive functioning.

Interference occurs when additional information, or multiple stimuli, interferes with the ability to retrieve or remember information. Two types of interference exist: proactive and retroactive. Proactive interference refers to instances when old learning interferes with new learning. For example, if you have learned to spell relief and later need to learn to spell receive, you may experience proactive inhibition. Retroactive interference refers to instances when new information interferes with the retrieval of old information. Interference is high when learning new material or when similar concepts are taught together in a short amount of time.

Metacognition

Metacognition was first defined by Flavell (1979) as the knowledge of one's own cognitive processes and the ability to monitor and regulate these processes. Simply, it is thinking about one's own thinking (Brown, 1987). As a sub-component of intelligence, metacognition controls higher-order information processing (Sternberg, 1987). Metacognitive strategies such

as planing and monitoring work in conjunction with cognitive strategies such as outlining and note taking. Metacognitive monitoring is a self check feedback system which directs attention and comprehension. For example, while reading, one monitors by asking oneself questions about the material and tracks attention. Adjustments are then made by changing reading speed or employing attention strategies such as underlining. Monitoring is used in mathematics by tracking the success of the strategy being used to solve the problem and then adjusting by employing other strategies if the current strategy is not successful.

Construct similarities

The cognitive processes involved in metacognition are encoding, storage, retrieval, and memory, and these processes appear to be controlled by the frontal lobes of the brain (Nelson, 1992). Patients with frontal lobe lesions have been found to show high susceptability to interference (Shimamura, 1994). If the same cognitive processes are being used by metacognitive monitoring and interference, it seems important to ask if there is a relationship between these two constructs. That is, to what degree is monitoring ability related to susceptability to interference.

An investigation of the relationship between interference and metacognitive monitoring has implications in education, individual differences in learning, and

advancement in cognitive functioning theory. Studies have shown that metacognitive monitoring can be taught, that is, individuals with low metacognitive abilities can develop their abilities (Zimmerman, 1989). It is possible that interference may be reduced by teaching monitoring skills to those with high susceptibility. If interference is due to a disturbance in the control process of monitoring and not due to basic memory problems (Metcalfe, 1994), then perhaps efforts can be made to focus on training individuals in appropriate monitoring strategies rather than emphasizing efforts on training memory.

Delimitations

The purpose of this study is to examine the possible relationship between interference and metacognitive monitoring. This study will not investigate the specific neurological nature of the metacognitive - interference relationship, rather it will investigate the empirical relationship between measures of these two constructs. This study is limited to the perceptual aspect of interference and the comprehension aspect of metacognitive monitoring.

Thesis

Interference and metacognitive monitoring ability appear to have related cognitive functioning controlled by the

frontal lobes of the brain. These two processes involve cognitive attention and monitoring may be a key component in suppressing unwanted thoughts or irrelevant information. Individuals who experience cognitive noise from a high susceptibility to interference may also experience difficulty in cognitive ability for metacognitive monitoring. Individuals who have greater monitoring abilities will have less interference, and individuals who have less monitoring ability will experience greater interference. That is, it can be expected that a positive relationship exists between susceptibility to interference and metacognitive monitoring abilities.

Specifically, this paper will investigate the following three questions:

1. Is there a relationship between interference and monitoring ability?
2. Can monitoring performance be predicted by interference measures and their components?
3. Does monitoring make a difference in the ability to predict scores on a math aptitude test?

Chapter 2

Literature Review

There is a vast amount of literature on metacognition and also interference. This paper will highlight the literature pertaining to construct definitions and development as they are related to the principles in the thesis. This will be followed by a review of the literature that pertains to the interaction of those principles.

Interference

The terms interference and inhibition have been used interchangeably in the literature, but there is increasing interest in making a distinction. McGeoch (1936) defines inhibition as the amount of decrease in the retention of the original material, and interference as the cause of the decreased retention, the task irrelevant material. Neill (1977), defines inhibition as the active suppression process that prevents irrelevant information from getting into working memory. It prevents a disruption in cognitive processing. A deficit in inhibition impairs processing by allowing irrelevant information to be activated, maintained and retrieved. Inhibition is commonly measured by negative

priming, memory intrusions, and relevant and irrelevant information activation during cognitive processing.

In contrast, interference is defined as the cognitive competition among multiple stimuli, processes, or responses and does not necessarily involve active suppression. Interference disrupts cognitive processing by slowing down the selection process. Common measures of interference are dual task processing, selective attention tasks, and measures of speed of access and response to stimuli. These distinctions are not universally accepted and models from different research areas of interference and inhibition use different definitions. While the definitions may not be clear, interference and inhibition are related constructs (Harnishfeger, 1995).

The ability to resist interference involves a knowledge base, strategy use, and working memory (Dempster, 1995). Studies of older adults have contributed to new views on the process of interference. The relationship between age and resistance to interference tends to be curvilinear. This important relationship has initiated a large body of literature concerning the developmental issues of interference.

Children and older adults are more susceptible to interference than middle adults (Connelly and Hasher, 1993). Recent studies have shown that this increased susceptibility

to interference in older adults in not due to memory decline, but rather due to a generalized slowing in inhibitory functioning (the ability to inhibit competing information) (Hasher and Zacks, 1988). Several investigators have shown strong evidence that a substantial portion of interference is due to response competition (MacLeod, 1991). Zacks (1995) supports this evidence in her findings that older adults do not have a deficit in working memory, it is actually enriched, but with irrelevant information. Older adults are slow to update information and, therefore, have difficulty suppressing unnecessary input.

Theorists disagree on whether the information disrupted by interference is permanently erased or if it can be eventually retrieved (Titcomb and Reyna, 1995).

Susceptibility to interference is implicated in individuals with schizophrenia and those with learning problems in reading and math (Harnishfeger 1995).

Metacognition

Metacognition is divided into two general components, the first is knowledge or awareness, which includes knowledge of one's strengths and weaknesses, knowledge of task difficulty and demands, and knowledge of strategies, and how and when to use them (Crooks and Stein, 1988). The second aspect is self-regulation, or control which includes planning, monitoring, and regulating (Pintrich and Schrauben,

1992; Zimmerman and Martinez-Pons, 1986). Pintrich, (1995) further defines this second aspect of self-regulation with subcomponents which include ease of learning, judgment of learning, feeling of knowing, and confidence judgments. While this study is concerned with measuring the monitoring aspect of self-regulation, it is important to note that other aspects of metacognition may occur simultaneously.

Metcalfe, Schwartz and Joaquim (1993), proposed that metacognitive monitoring plays a vital role in the operation of an efficient basic memory system and without this monitoring the memory system would get out of control. She further suggests that monitoring is a filter that assesses new incoming information and adjusts the memory storage system according to familiarity of the information. This allows the system to be responsive to changing input, allows a dynamic operation and can be used to explain interference errors and distortions that occur in memory.

Necessary components of metacognitive monitoring are knowledge base, strategy use, and working memory (Flavell, 1987, Metcalfe, 1994). These various factors are interrelated; for example, one needs knowledge of strategies before they can be used, and monitoring strategy use contributes to knowledge of the strategy. Studies show a causal relationship between metacognitive use and high math performance. Student failure is most often attributed to a

lack of metacognitive reflection before or during math problem solving (Peterson, 1988). Knowledge of strategies alone did not result in increased success; monitoring was necessary for success in math problem solving in junior high and high school age students (Carr and Jessup, 1995). Additionally, students who monitored were able to estimate their success in answering the problem correctly, and were able to diagnose and correct problems (Peterson, 1988).

In contrast, research has shown that metacognition does not improve math performance in older children (Siegler, 1989, Siegler & Shrager, 1984). In response, Carr and Jessup (1995) suggests that this discrepancy may be accounted for by a difference in the level of effort required to use a strategy. A newly learned strategy requires more reflection on how, why and when to use the strategy, whereas a strategy which has become automated will not require metacognitive monitoring.

Siegler (1989) also found that monitoring was not critical for math success in pre elementary school children Carr and Jessup (1995) suggests that perhaps because of immature cognitive development, it may be too difficult for young children to shift strategies. These children may have knowledge of other strategies, but the majority of cognitive energy is applied to learning whatever current strategy is being used to solve the problem. Siegler (1989) also suggests

that children may be unaware of the need to use different strategies.

Metacognitive studies show that individuals with math and reading learning disabilities demonstrate a lower ability to monitor (e.g., Pressley, Borkowski, & Schneider, 1987). Students without learning disabilities have greater ability to monitor (Flavell, 1979), and are more resistant to interference (Harnishfeger, 1995).

Construct similarities

Several studies (Metcalfe, 1994; Schimamura and Squire, 1986; Holmes, 1987) have suggested a relationship between metacognition and interference. Although each of these studies emphasize a different cognitive aspect, they converge on the fact that three themes, attention, cognitive capacity, and frontal lobe functioning are involved in both monitoring and interference.

Selective attention. The ability to focus attention on relevant information and ignore irrelevant cues in the environment is necessary in order to resist interference. Until recently, it was presumed that attention directly facilitates information processing. Information is received and attention intervenes allowing the selected, relevant information to be processed further. The stimuli which was ignored is not processed and dissipates passively (Van der

Heijden, 1981). Neill, Valdes and Terry (1995), however, suggest that the role of attention is to inhibit the processing of irrelevant information and allow the relevant information to be processed without interference from irrelevant information. Support for this theory can be found in populations that have cognitive deficits; they are unable to inhibit distracting information. Therefore, it appears that the role of attention in information processing involves not only selection of information to be processed, but suppression of background or irrelevant information.

The distinction between facilitation of relevant processing and inhibition of irrelevant processing has been tested using negative priming techniques. Negative priming describes the inhibitory effects of ignored stimuli in contrast to the facilitatory effects, or priming, produced by the stimuli being attended (Tipper, 1985). That is, negative priming demonstrates the inhibition of irrelevant processing and individuals who are more susceptible to interference show lower negative priming effects.

The effects of negative priming have been shown using the Stroop Color-Word Test, an interference sensitive task requiring selective attention (Dalrymple-Alford and Budayr, 1966). Furthermore, research shows negative priming effects with words, letters, drawings of objects, and unfamiliar shapes. Negative priming effects also occur across various

types of judgments including counting, matching categorization, and identification (Harnishfeger, 1995).

Attention is also an essential component of metacognitive monitoring (Flavell, 1979, Garcia and Pintrich, 1994). Monitoring involves giving the appropriate amount of attention or cognitive energy to information that is new and ignoring information that is known (Metcalfe, 1994).

Cognitive Capacity Research in developmental differences in interference show that interference is greater in younger children than in adults. The fact that children's resistance to interference increases with age may be a factor in children's increased memory span with age (Harnishfeger, 1995). Memory span is highly susceptible to interference effects and this difference was thought to be due to limited capacity in short term memory (Hasher and Zacks, 1988). Efforts to increase capacity used metacognitive devices such as mnemonic strategies, deliberate strategy use, organization, and chunking (Harnishfeger, 1995). Short term memory did increase using these devices, but these variables did not account for age differences in memory span (Dempster, 1981). Developmental changes in memory span may be attributable to developmental changes in interference sensitivity which is demonstrated by the fact that resistance to interference has its greatest change from elementary age children to early adolescence (Dempster, 1993).

Frontal lobe functioning Current evidence suggests that interference is functionally linked to the frontal lobes of the brain (Bjorklund & Harnishfeger, 1995; Dempster, 1993; Fuster, 1989). The frontal lobes are one of the last areas of the brain to develop and are not mature until 4-12 years of age. Inhibition, a frontal lobe function, also does not reach maturity until these ages (Harnishfeger, 1995). Schimamura and Squire (1986) have found that Korsakoff patients (alcoholics who have suffered damage to the diencephalon and frontal lobes due to thiamin deficiency from alcohol abuse) demonstrated lower metacognitive ability and also showed poor performance on the Wisconsin Card Sort Test, an interference sensitive task. Janowsky, Shimamura, and Squire (1989) found similar results: low metacognitive ability and high susceptibility to interference in patients with frontal lobe damage. Metcalfe (1993) has found that Korsakoff amnesiacs fail to release from proactive inhibition, but with a monitoring system in place, subjects release and perform in the manner of normal subjects. Frontal lobe functioning appears to be critical in monitoring and also in controlling functions that regulate interference (Shimamura, 1994).

Disturbances in metacognitive functions are characteristic of frontal lobe disturbances (Metcalfe, 1994). It has been suggested that there is a feedback loop in which one monitors and weights events being entered into memory.

Novel events are weighted more heavily, that is, we allocate more attention to new events. Individuals with better monitoring ability will be more able to selectively attend to the appropriate incoming information. Information is retrieved through the hippocampal memory system in an automized manner. The information is monitored and checked through frontal lobe processing.

Holmes (1987) states that children labeled with frontal system impairment demonstrate inadequate metacognitive functioning. Individuals with frontal damage do not check the retrieved information which results in inconsistent information and memory deficits.

Moscovitch (1989) describes a man with frontal lobe damage who has been married for 36 years, but states he has been married for 4 months. The patient further states that he has 4 children and comments that that's not bad for being married 4 months. He is aware of a problem, but not concerned. Metcalfe (1994) suggests that this type of inconsistency is not due to a memory problem, but to a metacognitive control process disturbance. Rohwer and Thomas (1989) state that several theorists (e.g., Borkowski, 1985; Brown et al., 1986; Pressley, Borkowski, & O'Sullivan, 1985; Rohwer, 1980) agree that differences in memory performance stem from differences in metacognitive processing.

It is necessary to monitor incoming information to determine if it is older, familiar information, or new information prior to associative memory storage (Metcalfe, 1994). If a person does not know that the information is familiar, no attempts will be made to search for associations in memory store.

Chapter 3

Method

Participants

Students from undergraduate Educational Psychology classes at the University of Nevada, Las Vegas, volunteered to participate in the study. A total of 91 subjects ranged in age from 19-42 with a mean age of 27 years. There were 28 male and 63 female subjects.

Instruments

Interference

Stroop Color and Word Test. The Stroop Color and Word Test (SCWT) (Stroop, 1935) was designed to measure interference and has been used to diagnose patients with frontal lobe injury. The test measures interference proneness or susceptibility to interference.

The SCWT consists of three timed tests, the word test, the color test, and the color-word test. Each test is on a separate page containing 5 columns with 20 words in each column and subjects are given 45 seconds to complete each test. Subjects are first asked to read aloud the word test, a page with the words "red, blue, and green" printed in black

ink. The order of presentation of the three words is randomized (see Appendix A.1).

Subjects are then given the color test, a page consisting of x's printed in red, blue, or green ink and are asked to name the color of the ink (see Appendix A.2). The final test, the color-word test, contains the words red, blue and green printed in colors other than the color name, e.g., the word "red" is printed in green ink, the word "blue" is printed in red ink (see Appendix A.3). Subjects are asked to read the color of the ink, not the word.

The word score (W), color score (C), and color-word (CW) scores are obtained by counting the number of words read in 45 seconds. A predicted color-word score (CW') is calculated by (W)(C) / (W + C). The Stroop interference score (SIS) is calculated by subtracting CW - CW'. A higher score (more words read), indicates the subject is less susceptible to interference.

The number of words read on the first page is generally twice as long as the number of words read the last page (Stroop, 1935). This difference is called "the color-word interference effect" (Stroop, 1935, p.1). Subjects are required to suppress the color word and name the color of the ink. These tasks require the same neuropsychological channels, thus creating interference. If an individual can separate the word and color naming stimuli, then suppress the

reading response and proceed with the color naming, that individual is less susceptible to interference. If an individual cannot suppress the word reading, and has to process both word and color before responding, that person is more susceptible to interference. The increased time for processing results in less words read and a lower interference score.

Test-retest reliability based on 456 subjects is .90 for the composite score. The component score reliability's were slightly lower: word = .88, color = .79 and color-word = .71. Normative studies show that results are highly consistent when similar age groups are compared (Stroop, 1935).

Wisconsin Card Sort Test The Wisconsin Card Sorting Test (WCST) (Grant & Berg, 1948) was designed to measure interference and differences between normal individuals and individuals with frontal lobe brain injury.

The WCST uses four stimulus cards and 128 response cards. The stimulus cards contain one red triangle, two green stars, three yellow crosses, and four blue circles (see Appendix B.1). The response cards vary in form: star, circle, triangle, or cross; color: red, green, yellow, or blue; and number of forms: one, two, three, or four forms on a card (see Appendix B.2).

Four stimulus cards are placed on the table and the subject is given the pile of response cards and asked to

match each of the response cards by placing it under the stimulus card with which they feel it should be matched. For each response, the subject is informed whether that response is right or wrong, but they are not told the correct sorting rule. When the subject has sorted correctly for seven responses in succession, the sorting rule is changed to the next category, i.e. color. The subject, however, is not told about the switch to the next sorting category. When the subject has seven successive correct responses for the color sorting rule, the category is changed to number. The series is then completed again for the categories of form, color, and number or until all cards have been used, or the series is complete.

A perserverative (interference) response occurs when the subject continues to sort according to a criterion after being told that is incorrect. For example, a perserverative error occurs if the subject continues to sort by color after the category has changed to number.

Scores are calculated for total errors, total correct, non-preservative errors, unique errors, and perserverative errors. The perserverative errors score was used as the interference measure (WIS). High WIS scores indicate high interference.

Generalizability coefficients for WCST range from .39 to .72 with a median of .60. Compared to traditional reliability

coefficients, generalizability coefficients in this range are moderate. The WCST subscales of percent perserverative responses and percent perseverative errors show fair reliability (Heaton, Chelune, Talley, Kay and Curtiss, 1993).

Metacognitive monitoring

Monitoring task. Monitoring is commonly measured using questionnaires, verbal reports, or prediction estimates, an estimate of how well one expects to perform on a given task. The prediction estimate method was used in this study because of the problem of artificially influencing responses with the other two methods (Pressley, 1992). Researchers have used prediction estimates to measure monitoring ability in reading and math (e.g. Baker & Brown, 1984; Flavel, 1979; Schommer, Crouse, & Rhodes, 1992; Schraw & Dennison, 1994). Levels of metacognitive ability measured by responses to a questionnaire have been shown to be related to ability to predict performance on math aptitude tests (Corkill, 1993). Subjects with higher levels of metacognition, specifically the strategy component, were able to more accurately estimate their performance on math aptitude tests (Corkill and Koshida, 1993; Corkill, 1994). This study used a prediction estimate monitoring task applied to a math aptitude test to measure metacognitive ability.

Fifteen math aptitude items were taken from the Kit of Factor Referenced Tests (Ekstrom, 1976). Separate answer

sheets were developed for the individual item monitoring group (IM) and the overall estimate group (OE).

The IM group answer sheet instructed students to solve each problem and evaluate their confidence in their solution to each question by making a slash mark on a scale from 0% to 100% confident. They were then asked to make an overall confidence estimate (OCE) of the number of questions they answered correctly (see Appendix C.1).

The OE group answer sheet instructed students to solve the problems and then estimate their OCE, that is, this group estimated their total score only, without monitoring success on each question (see Appendix C.2).

The MA score was calculated by subtracting the subject's actual math score from the subject's estimated score and the absolute value of this difference score was used as a measure of metacognitive monitoring ability. A score of zero would indicate perfect prediction, that is, no difference between the estimated and actual scores. Scores above and below zero indicate overestimation and underestimation of actual score.

Procedure

The SCWT and the WCST were administered individually and scored according to their instruction manuals. The time

needed to administer both tests ranged from 20 minutes to an hour.

The math test was administered in small groups of 10 - 15 students and subjects were given 30 minutes to complete the 15 item test using either the IM answer sheet or the OE answer sheet.

Chapter 4

Results

The study showed no significant results in regard to the expected relationship between interference and metacognitive monitoring. The results will be examined in the order the questions were presented.

Relationship between interference and monitoring

Correlations were calculated between the two interference measures and the metacognitive monitoring measure to estimate the strength of the relationships.

Interference was measured by using the SIS from the SCWT and the WIS from the WCST. Monitoring was measured using the MA score. Lower MA scores indicate more accurate estimates, higher SIS scores indicate lower interference, and lower WIS scores indicate lower interference. Means and standard deviations for these measures are reported in Table 1 (differences among these means are discussed in the next section).

Pearson-product correlation (see Table 2) showed no relationship between the interference scores and the MA score. In addition, the two interference measures, SIS and WIS, did not correlate with each other.

Table 1

Means and standard deviations for interference measures and monitoring ability

Measure	Mean	SD	N
SIS	2.43	6.29	91
WIS	9.09	10.23	91
MA	1.85	1.37	87

Prediction of monitoring

Intercorrelations between the interference component scores and MA demonstrated no relationships (see Table 2). However, various components of the WCST were related to each other. Three components related to the WIS, total correct (CT), total errors (ET), and non perserverative errors (PT). Total errors (ET) related to both total correct (CT) and non perserverative errors (NT), and total correct (CT) related to non-preservative errors (NT). The SCWT components (SIS and CW) did not relate to each other, nor did they relate to any WCST components.

Table 2

Intercorrelations among interference variables and MA

(Sample size in parentheses) *p<.05

Variable	CW	SIS	ET	CT	WIS	NT
MA	.135	.084	.016	.011	.013	.041
	(87)	(87)	(87)	(87)	(87)	(87)
CW		-.162	-.022	-.033	-.059	.011
		(91)	(91)	(91)	(91)	(91)
SIS			.033	.077	.043	.060
			(91)	(91)	(91)	(91)
ET				.839 *	.735 *	.861 *
				(91)	(91)	(91)
CT					.739 *	.675 *
					(91)	(91)
WIS						.500 *
						(91)

Note: MA = monitoring ability score

CW = predicted color word score on SCWT

SIS = interference score SCWT

ET = total errors on WCST

CT = total correct on WCST

WIS = perserverative errors on WCST

NT = non-perserverative errors on WCST

Differences between OE and IM groups

The means reported in Table 3 show that the IM group had observed, but not significant, scores in the expected directions. This group had lower monitoring scores, lower SIS scores, and higher WIS scores which would demonstrate higher monitoring ability and lower interference. However, independent t-tests for the dependent variables SIS, WIS, and MA show no significant differences among these variables.

Table 3

Differences in interference and monitoring ability between the IM and OE groups

	IM Group			OE Group		
Measure	Mean	SD	N	Mean	SD	N
SIS a	2.23	6.28	47	2.62	6.45	43
WIS b	9.27	9.22	47	8.95	11.44	43
MA c	1.73	1.45	45	1.97	1.29	42

a $t=.82$ $df=85$ $p>.05$

b $t=.29$ $df=88$ $p>.05$

c $t=-.15$ $df=88$ $p>.05$

Differences between actual and estimated scores on the math test for these groups are reported in Table 4. The OE group had an actual mean score of 9.53 and an estimated mean score of 10.69. The IM group had a higher observed but not significant actual mean score of 9.82, and an estimated mean score of 10.02. Both groups overestimated their scores.

The results of two independent t-tests for the dependent variables, estimated scores and actual scores, show no significant differences between the OE and the IM groups on math achievement or ability to predict scores.

Table 4

Differences in actual and estimated scores for OE group and IM group

	IM Group			OE Group		
Score	Mean	SD	N	Mean	SD	N
Actual [a]	9.82	2.94	47	9.53	3.07	43
Estimate [b]	10.02	3.09	45	10.69	2.70	42

a $t=-.46$ $df=85$ $p>.05$
b $t=1.07$ $df=85$ $p>.05$

This question was further investigated by examining the quality of the overall confidence estimate (OEC) for the IM group by calculating an item confidence estimate (ICE) score. The IM group made an estimate of how confident they were for each individual item (stated as a percent), as well as an estimate of their confidence of their overall score. The sum of confidence estimates for the individual items should be similar to the estimated overall score. The OCE scores and the actual scores were converted to percent (see Appendix C.1, C.2).

The ICE score was calculated by summing the percent of confidence for each item (25, 50, 75, or 100 percent confident, see Appendix C.2) and dividing by the number of items completed.

For example (see Appendix C.2), if a subject was 50% confident of the score for items #1-#4, 100% confident for items #5 and #6, 25% confident for items #7-#10, 50% confident for items #11-#14 and 0% confident for item #15, the ICE score would be 700 divided by 15 (the number of items attempted), or 46.6 percent.

The mean ICE score, 77.54 was similar to the mean OCE score, 71.41, and the difference between them was not significant.

Chapter 5

Discussion

The findings in this study are not consistent with theories that suggest a relationship between interference and metacognitive monitoring abilities.

The correlational studies show no evidence of relationship between susceptibility to interference and monitoring ability, it was expected that both measures would relate to monitoring. There was no correlation between the interference measures. The integrity of the WCST may have been challenged in some cases by students telling the sorting rules to those who had not yet taken the test. The WCST and SCWT are well established tests; both have high reliability indexes and demonstrate validity for measuring interference. The result may be explained by the possibility that these tests are measuring different aspects of interference. It has been hypothesized that there are different types of interference and these types of interference are dissociable (Dempster, 1995).

Given the absence of a relationship between the interference measures and MA, it is not surprising that the individual components of the interference measures did not relate to MA. However, the individual components of the WCST

did relate to each other. It was expected that the individual components of SCWT would also show a relationship.

The results of this study are inconsistent with previous research concerning monitoring and math score prediction. It was expected that those who monitored during the math test would be better predictors of their score than those who did not monitor. These results may be due to the restricted age range of the sample or due to problems in the monitoring ability measure.

Limitations

Instruments used to measure interference and monitoring ability may constitute a threat to the internal validity of this study. Although there is evidence to support the WCST and the SCWT are measuring interference, it is not certain what type of interference is being measured.

Current conceptualizations of metacognition purport that monitoring is a separate component of the regulating aspect of metacognition, and confidence estimates measure one aspect of monitoring. Although confidence estimates have been used to measure monitoring by established metacognitive researchers, the theory is based on the assumption that in order to predict you are monitoring by deliberately choosing a strategy based on your knowledge or previous success.

Additionally, monitoring is highly related to the

knowledge component of metacognition (Corkill & Koshida, 1993; Schraw & Dennison, 1994; Van Haneghan & Baker, 1989) and a more accurate measure of monitoring may need to incorporate a knowledge measure.

This study was conducted with a convenience sample of college aged students and therefore contains an age bias which limits the generalizability of the results. Subjects were college students primarily from upper division educational psychology classes, therefore, this sample is likely to be more intelligent than the general population.

Conclusion

Further studies need to be conducted including additional monitoring ability tasks and interference measures. A multi-trait, multi-method design may be useful to investigate these relationships. Although confidence estimation has been used to measure monitoring, it has primarily been used in conjunction with specific strategy teaching and may not be the most comprehensive measure of monitoring ability. A better measure of monitoring would include measures of other aspects of monitoring.

Although this study shows no evidence of a relationship between these constructs, further investigation is warranted due to the evidence which supports the theories that they are related.

Given future research establishes a relationship, then studies need to (1) determine the efficacy of teaching metacognitive monitoring strategies, and (2) to determine if there is a resultant reduction in interference.

If the ability to alter the basic cognitive function of interference by using the higher cognitive function of metacognitive monitoring is established, it may have implications in special education for individuals experiencing difficulties learning math and reading. This relationship may also have implications for individuals who are more susceptible to interference due to frontal lobe damage. Monitoring may reduce interference by increasing memory capacity, improving selective attention, and strengthening the frontal lobe feedback loop which may result in increased performance.

This relationship may also be of interest to industry which employs individuals to perform interference sensitive tasks. Monitoring may be incorporated into job training in efforts to reduce error due to interference and increase speed in task performance which may be slowed due to interference.

Training in metacognitive monitoring may also be investigated as a potential control of cognitive interference which affects behavior such as anxiety (Tobias, 1985) and motivation (Pintrich & Garcia, 1994).

Appendix A

Sample Stroop Color and Word Test

A.1 Word Test

RED	BLUE	GREEN	RED	BLUE
GREEN	GREEN	RED	BLUE	GREEN
BLUE	RED	BLUE	GREEN	RED
GREEN	BLUE	RED	RED	BLUE
RED	RED	GREEN	BLUE	GREEN

A.2 Color Test

XXXX	XXXX	XXXX	XXXX	XXXX
XXXX	XXXX	XXXX	XXXX	XXXX
XXXX	XXXX	XXXX	XXXX	XXXX
XXXX	XXXX	XXXX	XXXX	XXXX
XXXX	XXXX	XXXX	XXXX	XXXX

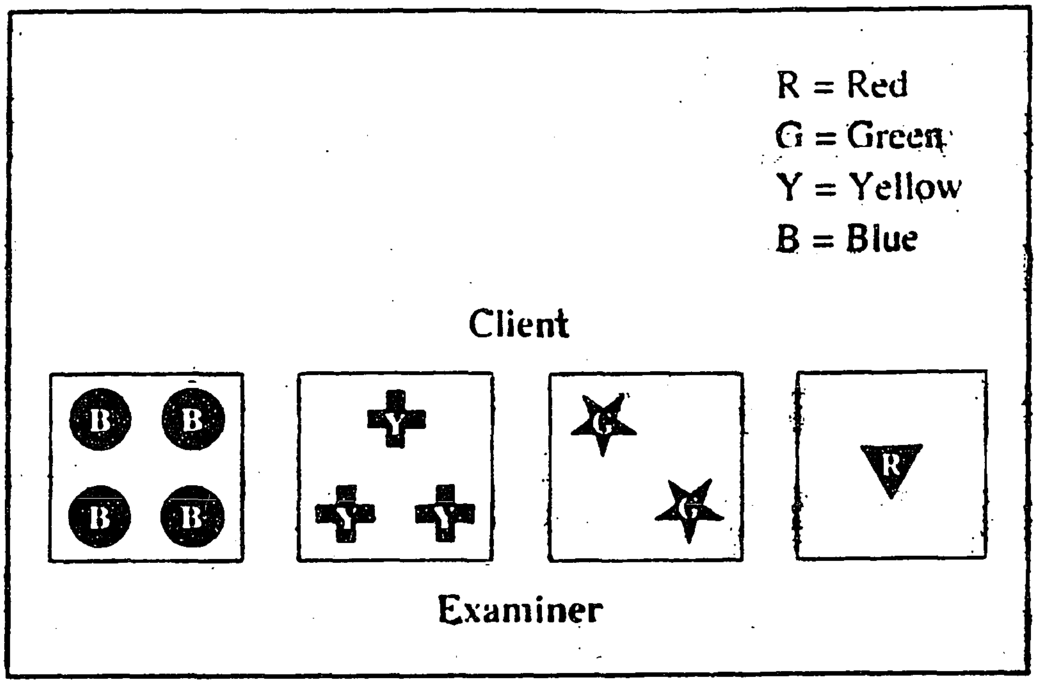
A.3 Color - Word Test

RED	BLUE	GREEN	RED	BLUE
GREEN	GREEN	RED	BLUE	GREEN
BLUE	RED	BLUE	GREEN	RED
GREEN	BLUE	RED	RED	BLUE
RED	RED	GREEN	BLUE	GREEN

Appendix B

Sample Wisconsin Cart Sort Test

B.1 Stimulus Cards



Appendix C

Math Aptitude Answer Sheets

C.1 Overall estimate (OE) group answer sheet

INSTRUCTIONS:

In this test you will be asked to solve some problems in mathematics and then rate your confidence in your ability to solve the problem. Solve each problem and write the letter of your answer in the blank next to the number on your answer sheet.

For example:

1. How many candy mints can you buy for 50 cents at the rate of 2 for 5 cents?
   A. 10
   B. 20
   C. 25

The correct answer is B, so you would write B in the answer column.

1. B

You will have 30 minutes to complete this test. Do not mark the question sheet.

ANSWERS

1. B
2. C
3. E
4. D
5. ✓ A
6. C
7. C
8. ✓ D
9. ✓ B
10. ✓ A
11. D
12. E
13. ✓ E
14. A
15. B

Estimated total correct 7

Calculation of Actual score

10/15 = 66%

Calculation of OCE score

7/15 = 46%

C.2 Individual item monitoring (IM) group answer sheet

INSTRUCTIONS:

In this test you will be asked to solve some problems in mathematics and then rate your confidence in your ability to solve the problem. Solve each problem and write the letter of your answer in the blank next to the number on your answer sheet. Next, rate your confidence in your answer by putting a hash mark at your confidence level. A rating of 0% indicates that you do not know the answer, you are guessing. A rating of 100% indicates that you are sure of your answer. You will have 30 minutes to complete the test.

For example:

1. How many candy mints can you buy for 50 cents at the rate of 2 for 5 cents?
   A. 10
   B. 20
   C. 25

You choose answer B and you are somewhat sure of your answer, so you write B in the blank next to number 1 in the answer column and make a hash mark on the confidence scale near the 50% mark.

1.__B__ 0%----------25%---------50%---------- 75%----------100%

If you were not sure of your answer you would make a hash mark near 0%.

1.__B__ 0%----------25%----------50%---------- 75%----------100%

ANSWERS

1.__B__ 0%----------25%---------50%---------- 75%----------100%
2.__A__ 0%----------25%---------50%---------- 75%----------100%
3.__E__ 0%----------25%---------50%---------- 75%----------100%
4.__D__ 0%----------25%---------50%---------- 75%----------100%
5.__E__ 0%----------25%----------50%---------- 75%---------100%
6.__A__ 0%----------25%----------50%---------- 75%---------100%
✓7.__C__ 0%---------25%----------50%---------- 75%----------100%
8.__C__ 0%---------25%----------50%---------- 75%----------100%
9.__D__ 0%---------25%----------50%---------- 75%----------100%
✓10.__A__ 0%---------25%----------50%---------- 75%----------100%
✓11.__B__ 0%----------25%---------50%---------- 75%----------100%
12.__E__ 0%----------25%---------50%---------- 75%----------100%
13.__C__ 0%----------25%---------50%---------- 75%----------100%
14.__B__ 0%----------25%---------50%---------- 75%----------100%
✓15.__A__ 0%----------25%----------50%---------- 75%----------100%

Estimated total correct__13__

Calculation of Actual score

11/15 = 73%

Calculation of ICE score

700/15 = 46.66%

Calculation of OCE score

13/15 = 86%

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