Actively Open-Minded Thinking Dispositions and Improvement in Critical Thinking

DRAFT ONLY

Abstract.

Introduction

Jonathan Baron defines *Actively Open-minded Thinking* (AOMT) as "the willingness to search actively for evidence against one's favoured beliefs, plans or goals and to weigh such evidence fairly when it is available" (2002, p. 1). There is a great deal of empirical evidence that AOMT is not widespread in the general population. In particular, there is evidence for a pervasive "myside bias" in thinking (also known as 'belief bias" or "confirmation bias"). People have a tendency to think in ways that favour their current views and goals. They fail to consider alternatives and do not weigh counterevidence fairly. This bias effect is found across a wide variety of reasoning tasks, age groups and intelligence levels (See Evans et al. 1983, Markovits and Nantel 1989, Broniarczyk and Alba 1994, Baron 1995, Kardash and Scholes 1996, Klaczynski and Gordon 1996, Klaczynski et al. 1997, Stanovich and West 1997, Nickerson 1998, Stanovich et al. 1999). Actively open-minded thinking is simply the disposition and ability to avoid such bias: to search actively for evidence against views one already accepts and to weigh such counterevidence fairly.

AOMT is a core component of c*ritical thinking*. Critical thinking is often defined in fairly broad terms, but here we take it to be a collection of skills and dispositions which include the skills of argument analysis (detecting, clarifying and analysing the structure of arguments), evaluation (of arguments, premises and explanations) and logical inference (drawing valid conclusions from given information). AOMT is frequently stressed as a vital characteristic of the critical thinker (Nickerson 1987, Ennis 1989, Baron 1991, 1994, Voss et al. 1991, Johnson and Zechmesiter 1992, Kuhn 1991, 1993, Sá et. al 1999). Clearly, the ability and disposition to impartially seek out evidence that might contradict a favoured opinion or goal and to weigh such evidence impartially is a necessary component of the ability to evaluate arguments, premises and explanations.

What factors affect individual differences in AOMT? One factor appears to be cognitive ability or general intelligence: greater cognitive ability is correlated with less bias in the evaluation of evidence (Stanovich and West 1998).[1] In addition however, it has consistently been shown that various *beliefs about thinking itself* (or *thinking dispositions*) are associated with AOMT. Some beliefs about thinking appear to counteract myside and other biases, while others tend to encourage them. (Schommer 1990, 1993, Baron 1991, Stanovich and West 1997, 1998, Stanovich et al. 1999, Klaczynski et al. 1997, Kardash and Scholes 1996).

For example, Stanovich and West (1997, 1998) developed a questionnaire asking subjects to indicate their level of agreement or disagreement (each on a 3 point scale) with statements such as the following:

- Changing your mind is a sign of weakness.

- Intuition is the best guide in making decisions.
- Difficulties can usually be overcome by thinking about the problem, rather than through waiting for good fortune.
- There is nothing wrong with being undecided about many issues.

They found positive correlations between open-minded attitudes, as measured by this questionnaire and performance on a wide variety of reasoning tasks. Open-minded attitudes were associated not only with reduced myside bias in argument evaluation and syllogistic reasoning, but also with performance on Wason's (1996) four-card selection task, statistical reasoning tasks (requiring the use of base-rate information), hypothesis testing and judgements of covariation (the ability to judge when two variables are correlated). These correlations remained even after differences in cognitive ability had been factored out.

These associations suggest that at least part of the reason why people fail to conform to a normative standard of good, unbiased thinking is that they have *different* standards (Baron 1991). If people do not believe that objectivity, impartiality and openness to alternatives are a good thing, they will not reason according to such standards, even if they are able to. If instead people believe that 'sticking to your guns' (even in the face of contrary evidence) is an admirable trait or that 'thinking too much' is a bad thing, they will tend to think according to that standard. They may either not rely on reasoning at all when thinking about a problem or decision (relying instead on gut instinct, or authority figures) or they will selectively apply their cognitive abilities only when their beliefs or goals are threatened. (Klaczynski et al. 1997). By *their* lights however, this is the right and proper way to proceed.

This obviously has implications for the *teaching* of thinking. If we want to help students improve their critical thinking skills, it may be that we will need to alter their beliefs about thinking, the normative standards they apply in assessing their own thinking and the thinking of others. As Baron puts it '… people who think poorly by ideal standards may reject those standards. They may think they are thinking well when they are actually thinking poorly. This argument implies that the teaching of thinking may involve modification of people's standards. It is not just a matter of prodding people to live up to the standards they already hold.' (Baron 1991, p. 169).

Indeed, many authors agree that we cannot expect to improve cognitive capacities very much through teaching. Thinking dispositions and attitudes, by contrast are expected to be much more malleable. Hence, a critical thinking course emphasising and encouraging these dispositions might lead to a significant improvement in the skills of critical thinking. (Baron 1991, 2002, Stanovich and West 1997).

However, there has been very little research to date which is directly focused on these implications for teaching. Most of the research referred to above has examined individual differences in AOMT and their relation to factors such as cognitive ability and attitudes. In these studies, subjects complete a battery of tests on a single occasion and the relationships between the variables measured are investigated. None of these studies have attempted to measure gains in critical thinking as a result of instruction in AOMT, or whether open-minded thinking dispositions can affect such gains.

As part of a three year study to evaluate and compare teaching methods for improving critical thinking at the undergraduate level (Monash University 2006), we attempted to investigate some of these issues. In particular, our study addresses the following questions:

1. Is there any association between open-minded thinking dispositions and critical thinking skills, as measured by standardized tests?
2. Can a critical thinking course which emphasises and encourages AOMT lead to significant improvements in critical thinking skills, as measured by standardised tests?
3. Is there any association between open-minded thinking dispositions and individual gains in critical thinking ability over the period of such a course?

The standardized critical thinking tests used in most research on the teaching of critical thinking do not measure AOMT directly, since they make no attempt to measure prior belief (Stanovich and West 1997, p. 343). Nonetheless, given the robust correlations between open-minded attitudes and performance on a wide variety of reasoning tasks, it seems likely that open-mindedness would also be correlated with performance on these tests. Furthermore, if improvement in critical thinking ability can be achieved by increasing open-minded attitudes in students, we would expect to find a positive correlation between such attitudes and individual gains on standardized tests of critical thinking.

Method

Participants

The participants were 57 undergraduate students (30 men and 27 women) recruited from a first-year second-semester philosophy course in critical thinking. Ages ranged from 18 (8 students) to 34 (1 student). The median age was 20 years. Participants were recruited in the following way. All students taking the course were required to complete a pre- and post-test of critical thinking ability. They were informed about the study and asked to complete a voluntary consent form giving permission for their pre- and post-test scores to be used for the purposes of the study. A grade incentive was also offered. Assessment for the course involved four homework exercises – the final grade for the course was an average of the grades for each exercise. However, students were informed that their highest pre- or post- test score would replace their lowest score on their (submitted) homework exercises.

Of the 78 students enrolled in the course at the start of the semester, 57 (73%) consented to be part of the study. All 57 of those students completed the pre-test and 49 (86%) also completed the post-test. Of the 8 students who failed to complete both tests, 3 dropped out of the course and 5 failed to attend the post-test session.

Test instruments

Two tests of critical thinking skill were administered; the California Critical Thinking Skills Test (CCTST, refs) and the Critical Thinking section of the Graduate Skills Assessment test (GSA, refs). Both are timed (45 minute) multiple-choice tests. Each test comes in two equivalent forms: A and B. In addition, students were asked to complete the Thinking Dispositions Questionnaire (TDQ) developed by Stanovich and West (1997, 1998, 2003).

Procedure

Students completed the CCTST and GSA tests during the scheduled tutorials for the course. Each tutorial was two hours in duration. The CCTST and GSA pre-tests were completed in the first tutorial (week 2 of the course). The CCTST and GSA post-tests were completed in

the final tutorial (week 13 of the course). A small number of students who were unable to attend the tutorials completed the tests in separate sessions (11 for the pre-test, 5 for the post-test).

Forms A and B of each test were randomly distributed among the participants for the pre-test and students were given the opposite test form for the post-test. The tests were administered under examination conditions. There were four tutorial groups in total. Class sizes were 8, 19, 18 and 14 for the pre-tests and 9, 18, 11 and 14 for the post-test. Students were not informed of their test scores until after the end of the course.

Students were also asked to complete the Stanovich and West (2003) Actively-open minded Thinking Dispositions Questionnaire (TDQ). The questionnaire was placed on the website for the course and made available for the first three weeks of the course. Students were allowed to complete it in their own time. The questionnaire was scored automatically, but students were not informed of their score.

The critical thinking course

The critical thinking course was a 13 week programme consisting of one (1 hour) lecture per week and one (2 hour) tutorial class per week. As described above, the first and last tutorials of the course were given over to pre- and post- testing. The first two lectures consisted of some motivation for the course and some general topics in the theory of reason and argument. This was followed by three lectures on argument analysis (identifying arguments, argument structure, textual analysis) and four lectures on argument evaluation (criteria for evaluation, formulating objections and replies and identifying unstated assumptions). The final four lectures were on fallacies. The material covered in the lectures was also contained in a short textbook, specially written for the course.

The first hour of each tutorial consisted of a review of material covered in the lectures, along with some short exercises or quizzes (generally multiple-choice). This was followed by an hour of argument analysis and evaluation practice. For this purpose, students were required to read a section (approximately 3,000 words) each week from Peter Singer's book *The President of Good and Evil* (Singer, 2004). The topics covered in these readings were taxation policy, the ethics of stem-cell research, capital punishment and the legitimacy of pre-emptive strikes against nations accused of harbouring terrorists. There were four tutorial groups, taught by three different tutors. Class sizes were (approximately) 10, 19, 18 and 26 (there was of course some variation throughout the semester).

Assessment took the form of four homework exercises (there was no final exam). Each exercise consisted of two main parts. The first part consisted of reading comprehension and logical reasoning multiple-choice questions taken from the LSAT prep-tests (LSAC 2002). The second part asked students to produce a written analysis and evaluation of an argument from Singer's book.

AOMT teaching strategies

We made an effort to introduce into the course some content and exercises specifically aimed at increasing actively open-minded thinking dispositions and abilities. Many of these teaching methods and strategies were culled from the work of Baron and others in the AOMT research literature, while others were devised by the present authors. They included the following:

1. Students were taught about some of the empirical evidence for myside bias and the evidence that open-minded thinking dispositions reduces these biases and improves thinking. This follows up on a suggestion of Baron's, that " … we can change conduct by convincing people that AOMT is better, that is, by teaching them about the psychological research showing its benefits." (2002).

2. Some attempt was made to explicitly teach and endorse the beliefs about thinking that are associated with AOMT (for example, that changing your mind and being open to evidence that goes against a favoured belief is a characteristic of a good thinker).

3. For multiple-choice practice questions (including homework exercises) students were encouraged to work through each potential answer and justify their evaluation of it. That is, they were encouraged not just to pick what they thought was the right answer, but to actively look for evidence against their choice, by carefully considering the alternatives.

4. In homework exercises, there was an emphasis on questions that focused on the ability of students to find alternative explanations or counter-evidence for a given claim.

5. In the argument evaluation section of the course, students were taught that ideally, a successful arguments must be 'complete', that is, all the relevant evidence for and against must be considered and evaluated. Even if the premises of an argument are true, relevant to the conclusion and sufficient to establish the conclusion, an argument may still fail to be successful if it does not take into account counter-arguments or possible objections to the reasoning or premises.

6. In the second part of each tutorial, students were required to consider the other side of each argument they were given to analyse and evaluate. At the start of the tutorial, students were asked to express an opinion about the topic under consideration. They were then split up into two groups, those in agreement with the conclusion of the argument and those opposed to it. Students were then asked to offer counter-arguments and counter-examples to the view they endorsed. Tutorial worksheets with specific guidance and discussion questions for each group were used to assist students and tutors in this exercise.

Results

Firstly, no significant differences were detected between men and women on any of the pre- or post-test measures, nor on any of the measures of gain. We found no statistically significant correlations between age and any of the variables measured.[2]

1.The relationship between open-minded thinking dispositions and critical thinking ability

Table 1 shows the pre-test scores for the CCTST, GSA and TDQ. Means are reported in the following format [L **M** U] (s.d.), where **M** is the mean, s.d. the standard deviation and L and U are lower and upper bounds for the 95% confidence interval. These means were calculated only for subjects who completed all three tests.

For the GSA, the raw scores out of 34 were rescaled by the test publisher, in order to correct for the difference in difficulty between the two test forms These rescaled scores were then converted to a percentage score, using the maximum values supplied by the publisher (859 for Form A and 870 for Form B).

Table 1
Mean pre-test scores on critical thinking tests and thinking dispositions questionnaire

Test	**Mean** *n* = 52
CCTST (%)	50.87 **54.92** 58.97 (14.53)
GSA (%)	44.82 **47.81** 50.80 (10.75)
TDQ (%)	69.45 **72.3** 75.15 (10.23)

Table 2 shows the correlation coefficients for the relation between students' pre-test scores on the CCTST, GSA and TDQ. GSA and CCTST test scores were strongly correlated with each other (r = 0.645, $p < 0.01$). In addition there were significant correlations between open-minded attitudes, as measured by the TDQ and performance on both the CCTST (r = 0.319, $p < 0.05$) and the GSA (r = 0.408, $p < 0.01$).

Table 2
Correlations between initial open-minded thinking attitudes and critical thinking pre-test scores

	TDQ	**CCTST**	**GSA**
TDQ	-	.319* *n* = 52	.408** *n* = 52
CCTST	-	-	.645** *n* = 56
GSA	-	-	-

** $p < 0.01$ (two-tailed). * $p < 0.05$ (two-tailed)

To get an idea of the difference a high TDQ score makes to critical thinking ability, we split our sample into two subgroups. The 'High open-minded' subgroup consists of the students

with the 26 highest scores on the TDQ, while the 'Low open-minded' subgroup consists of those students with the 26 lowest TDQ scores. Table 3 shows the difference between mean GSA and CCTST pre-test score for these two subgroups. The mean CCTST score for the Low open-minded group was 49.32% while that for the High open-minded group was 60.52% – a difference of 11.2 percentage points. The difference between the two groups was statistically significant at the 0.05 level ($t(50)=2.99$, $p = 0.004$). The mean GSA score for the Low open-minded group was 42.62%, while for the High open-minded group, the mean was 53% – a difference of 10.38 percentage points. This difference was also statistically significant at the 0.05 level ($t(50) = 3.95$, $p < 0.001$). The difference in pre-test scores for the two groups is shown in **Figure 1**.

Table 3
Mean critical thinking pre-test scores for students with highest and lowest TDQ scores

	Low Open-Minded *n* = 26	**High Open-Minded** *n* = 26	**% Difference**
TDQ %	61.15 **64.37** 67.60 (7.97)	78.46 **80.22** 81.99 (4.37)	12.24 **15.85** 19.46
CCTST %	43.85 **49.32** 54.79 (13.55)	55.07 **60.52** 65.97 (13.5)	3.67 **11.20** 18.73
GSA %	38.89 **42.62** 46.35 (9.23)	49.07 **53.00** 56.93 (9.72)	5.10 **10.38** 15.66

The correlation between open-minded thinking dispositions and critical thinking ability was maintained when the students were tested again at the end of the course. Table 4 shows the correlation coefficients for the relationship between pre-instruction TDQ score and CCTST and GSA post-test scores. There were significant correlations between TDQ score and both GSA (0.47) and CCTST (0.49) post-test scores (in both cases, $p < 0.001$). CCTST and GSA post-test scores were also strongly correlated ($r = 0.691$, $p < 0.001$).

Table 4
Correlations between initial open-minded thinking attitudes and critical thinking post-test scores

	TDQ	**CCTST**	**GSA**
TDQ	-	0.489** *n* = 46	0.470** *n* = 45
CCTST	-	-	0.685** *n* = 48
GSA	-	-	-

** $p < 0.01$ (two-tailed). * $p < 0.05$ (two-tailed)

Figure 1

Relationship between AOMT and critical thinking pre-test scores

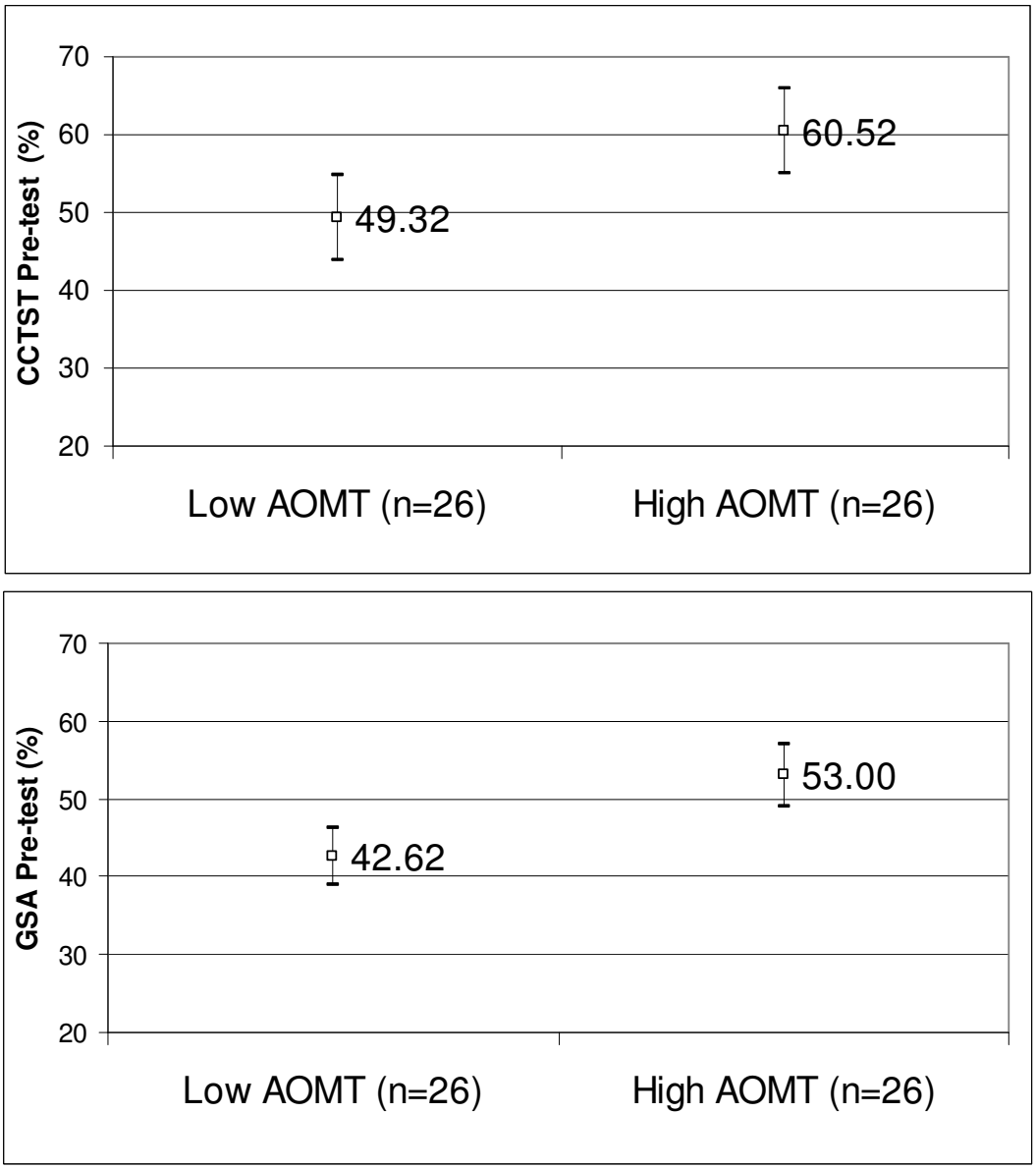
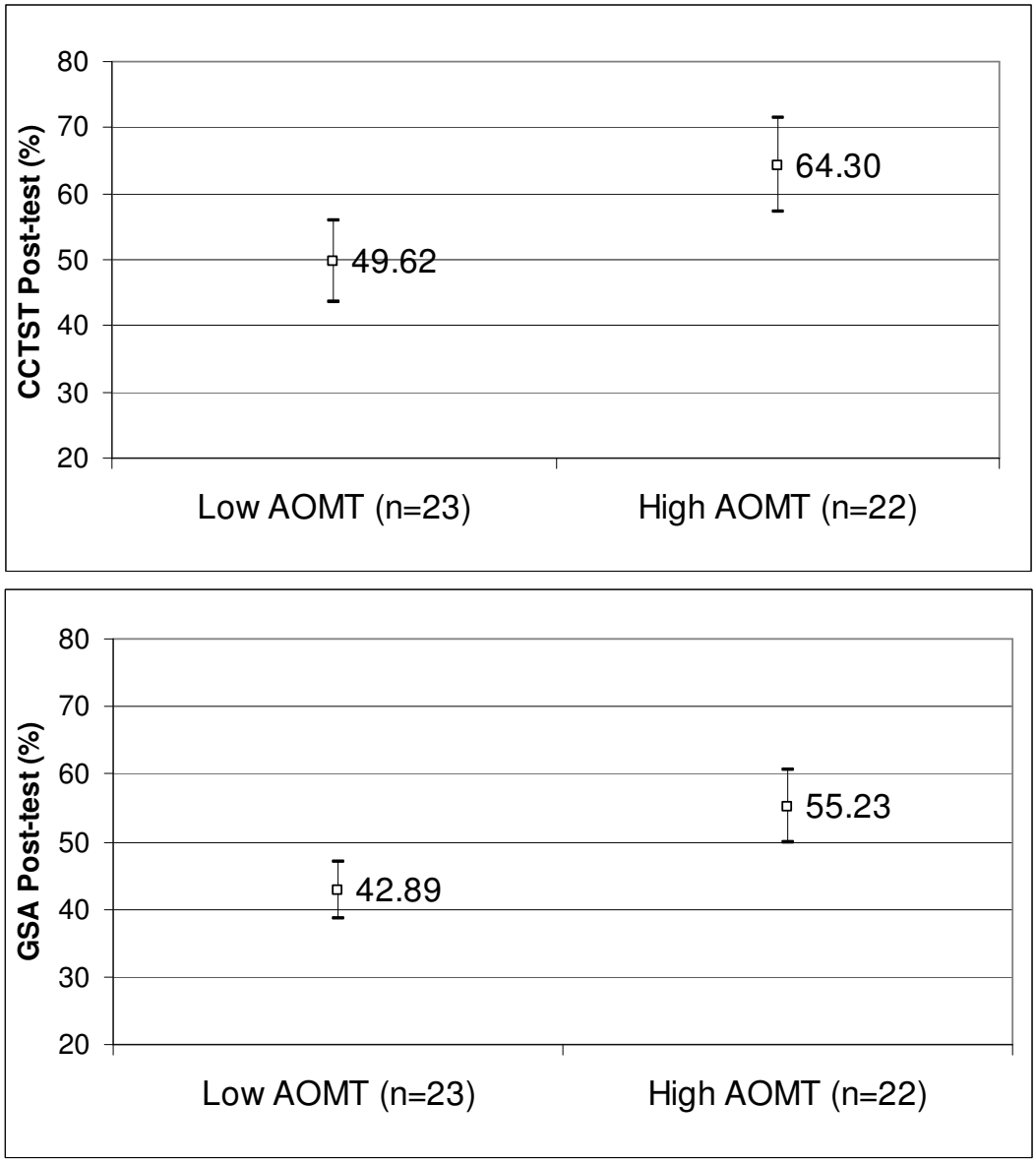


Table 5 compares mean post-test scores on the CCTST and GSA for the High open-minded and Low open-minded subgroups described above. For the low group, the mean CCTST post-test score was 49.6%, while that for the high group was 64.3%. This difference of 14.8% (± 8.92%) was statistically significant at the 0.05 level ($t(44)=3.351$, $p = 0.002$). For the GSA, the post-test difference between the Low open-minded and High open-minded subgroups was 12.3% (± 6.56%). Again, this difference was statistically significant ($t(43)=3.792$, $p < 0.001$). The difference in post-test scores for the two groups is shown in **Figure 2.**

Table 5
Mean critical thinking post-test scores for students with highest and lowest TDQ scores

	Low Open-Minded *n* = 23	**High Open-Minded** *n* = 22	**Difference**
CCTST %	43.62 **49.62** 55.83 (14.36)	57.22 **64.30** 71.39 (15.99)	5.91 **14.83** 23.76
GSA %	38.69 **42.89** 47.09 (9.71)	49.89 **55.23** 60.57 (12.04)	5.78 **12.34** 18.90

Figure 2
Relationship between AOMT and critical thinking post-test scores



2. The relationship between open-minded thinking dispositions and gains in critical thinking ability

Tables 6a and 6b shows the correlation coefficients for the relationship between pre-instruction TDQ score and gain scores on the critical thinking tests. For each student, we calculated both an *absolute* gain score (the difference between their pre- and post-test score) and a *proportional* gain score. The latter is just the difference between pre- and post-test score expressed as a percentage of how many points each student could have earned (or lost). For example, a student who scored 56% on the pre-test and 62% on the post-test would earn a proportional gain score of (62 - 56)/(100-56) = 6/44 = 13.63%, whereas a student who scored 80% on the pre-test and 75% on the post-test would earn a proportional gain score of -5/80 = -6.25%.[3]

Significant positive correlations were found between TDQ score and gains in critical thinking as measured by the CCTST. The correlation between TDQ score and absolute CCTST gain score was 0.294 ($p = 0.047$). The correlation between TDQ score and proportional CCTST gain score was 0.328 ($p = 0.026$). Although CCTST and GSA test scores were correlated with each other, CCTST and GSA *gain* scores were not correlated ($r = 0.047$, $p = 0.749$ for the absolute gain scores, $r = 0.103$, $p = 0.486$ for proportional gain scores). No significant correlation was found between TDQ score and gains on the GSA.

Table 6a
Correlations between TDQ score and absolute gain scores

	TDQ	CCTST gain	GSA gain
TDQ	-	0.294* $n = 46$	0.18 $n = 45$
CCTST gain	-	-	0.001 $n = 48$
GSA gain	-	-	-

* $p < 0.05$ (two-tailed)

Table 6b
Correlations between TDQ score and proportional gain scores

	TDQ	CCTST prop. gain %	GSA prop. gain %
TDQ	-	0.328* $n = 46$	0.252 $n = 45$
CCTST prop. gain %	-	-	0.059 $n = 48$
GSA prop. gain %	-	-	-

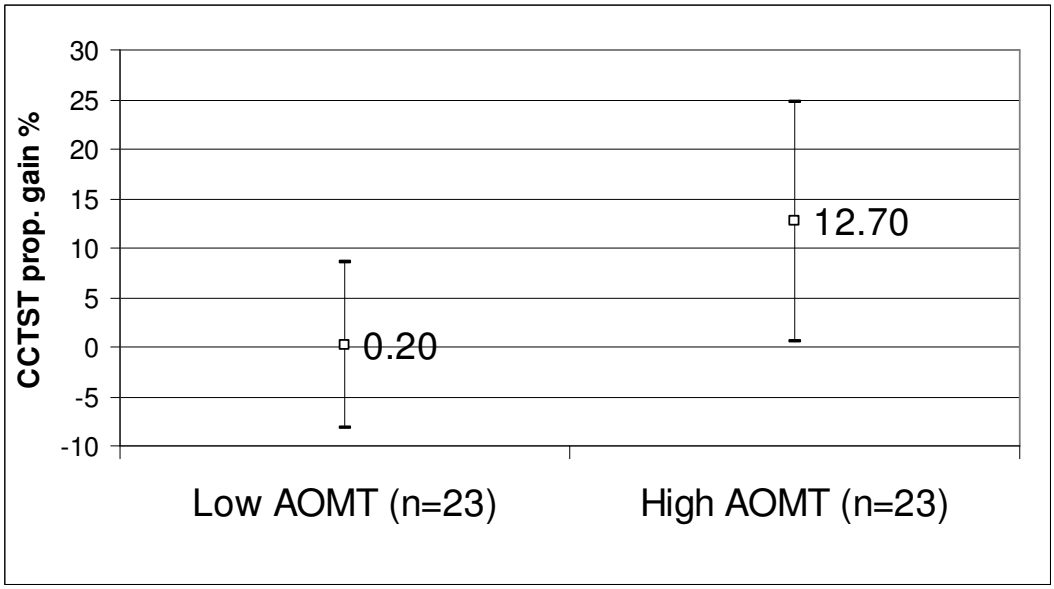
Table 7 compares gain scores on the CCTST for the Low Open-minded and High open-minded subgroups defined above. The mean proportional gain score for Low open-minded students was 0.2%, while that for the High open-minded students was 12.7%. The difference between these groups did not achieve statistical significance however, possibly due to the

large variance in the proportional gain scores. See **Figure 3**.

Table 7
Mean CCTST gain scores for students with highest and lowest TDQ scores

	Low Open-Minded *n* = 23	**High Open-Minded** *n* = 23	**Difference**
CCTST prop. gain %	-8.23 **0.22** 8.67 (19.54)	0.66 **12.70** 24.73 (27.8)	-1.81 **12.48** 26.77
CCTST abs. gain %	-4.91 **-0.51** 3.89 (10.18)	-1.64 **3.71** 9.05 (12.36)	-2.51 **4.22** 10.95

Figure 3
Effect of AOMT on CCTST gains



3. Gains in critical thinking scores

Table 8 summarises the pre- and post- test means and gain scores for the CCTST and GSA. Here means include only those students who completed both pre- and post- tests. The mean proportional gain on the CCTST was 6.6%, while the mean proportional gain on the GSA was 6.5%. Neither of these gain scores is significantly different from zero at the 0.05 level.

Table 8
Pre- and Post-test means and mean gain scores for CCTST, GSA and TDQ

	CCTST *n* = 49	**GSA** *n* = 48
Pre-test %	51.32 **55.46** 59.60 (14.41)	45.17 **48.11** 51.04 (10.1)
Post-test %	52.62 **57.26** 61.90 (16.16)	45.23 **48.75** 52.26 (12.11)
Gain %	-1.40 **1.80** 4.99 (11.13)	-1.76 **0.64** 3.05 (8.28)
Prop. gain %	[-0.2 **6.6** 13.5] (23.9)	[-3.31 **1.52** 6.35 (16.62)

Discussion

As predicted, we found that actively open-minded thinking attitudes were correlated with critical thinking ability as measured by standardized tests. Initial TDQ scores were correlated both with the pre-test scores and with the post-test scores for both the CCTST and the GSA. It is interesting to compare the size of these correlations - 0.319 and 0.409 for the pre-tests and 0.489 and 0.48 for the post-tests - with those obtained by Stanovich and West (1998). For example, they report correlation coefficients ranging from 0.226 to 0.296 for the relationship between TDQ score and performance on their argument evaluation task (AET) – a test specially designed to measure the ability of subjects to judge arguments independently of prior belief in the conclusion.[4] For the syllogistic reasoning task, they reported correlations ranging from 0.277 to 0.329, while for statistical reasoning the correlations ranged from 0.201 to 0.277 ($p < 0.001$ in all cases).

Although the correlations between ability and open-minded attitudes found in the present study are somewhat larger than those reported by Stanovich and West, they are still of only moderate magnitude. Nonetheless, for the CCTST, there was a difference of 3.8 points (0.79 pre-test standard deviations) between mean scores for students in the 'low' (below median) open-minded subgroup and those in the 'high' open-minded subgroup. For the GSA the difference was 5.8 points (1.1 standard deviations).

What factors affected students' gains in critical thinking skills? We found no difference in mean gains between men and women and no differences due to age. Nor were (proportional) gains correlated with initial ability, as measured by the pre-tests. However, initial TDQ score did predict gains in critical thinking as measured by the CCTST: the correlation coefficients were 0.294 for absolute gain scores and 0.328 for proportional gain scores. For CCTST proportional gain scores, we recorded a difference of 12.5% (0.6 standard deviations) between students in the low open-minded subgroup and those in the high open-minded subgroup. Interestingly however, this association did not hold when we examined GSA gain scores and indeed, CCTST and GSA gain scores were not correlated with each other. Perhaps the CCTST is more sensitive to change in ability than the GSA, or perhaps the two tests measure distinct (but clearly related) constructs, one more susceptible to change than the other.

To some extent, these results support Baron's hypothesis that we could improve students' critical thinking skills by attempting to instil open-minded attitudes. However, a great deal of caution is needed in interpreting these results. Obviously, the fact that there is a positive correlation between open-minded attitudes and gains in critical thinking ability does not by itself warrant the conclusion that the relation between the two is a causal relation. So it does not follow that making students more open-minded will necessarily lead to improvements in critical thinking. Open-minded attitudes and gains in critical thinking ability might both be explained by some distinct underlying factor. One such possible underlying factor might be cognitive ability or general intelligence.

There is some evidence that open-minded attitudes are positively correlated with cognitive ability; Stanovich and West (1998) report correlation coefficients of 0.139 and 0.337 in separate studies. Furthermore, it may well be that pre-instruction cognitive ability is itself positively correlated with improvement in critical thinking (though we know of no studies that have directly tested this hypothesis).

Since we made no attempt to measure cognitive ability in our subjects, we could not determine whether this variable was associated with gains in open-minded attitudes or critical thinking test scores. However, a positive correlation between *gains* in open-minded attitude scores and *gains* on the critical thinking tests would provide some weak support for Baron's hypothesis. In this study, we found only very slight (and non-significant) positive correlations between TDQ gain scores and critical thinking test scores. The highest of these was between TDQ gain and CCTST gain: $r = 0.267$, $p = 0.177$. The high drop-out rate between TDQ pre- and post-test (54.8%) make this result difficult to interpret however.

On the other hand, although we made an effort in the present course to teach students about the benefits of AOMT and provided them with numerous exercises specifically aimed at increasing AOMT, and although we did measure a significant increase in open-minded attitudes (14%), overall gains on the critical thinking tests for the class as a whole were very disappointing. The mean proportional gains for the class were 6.6% on the CCTST and 6.5% on the GSA. Neither of these gains was statistically significant. In an earlier version of the course, taught at the same university, using the same teaching format, textbook, examples and assessment programme but with no AOMT exercises, we recorded mean proportional gains of 7.8% on the CCTST and 11.4% on the GSA and both of these gains were statistically significant. [5] Hence, we have found little evidence that encouraging AOMT makes a substantial difference to gains in critical thinking test scores. Clearly, improving critical thinking by changing attitudes to thinking, if it is possible at all, is not *easy*.

Limitations and further research

There are several limitations of the present study that point to the need for further research. One limitation has already been mentioned: we made no attempt to measure cognitive ability in our subjects. We therefore have no way of establishing whether the correlation between open-minded attitudes and gains in critical thinking would remain once differences in pre-instruction cognitive ability have been factored out. That is, we cannot tell how much of the variation in critical thinking gain scores can be explained by initial open-minded attitudes alone, independent of initial cognitive ability. Nor were we able to establish whether pre-

instruction cognitive ability is correlated with gains in critical thinking test score or whether (as seems plausible) cognitive ability is unaffected by instruction in critical thinking.

This deficit would not be difficult to remedy. For example, reliable measures of cognitive ability can be obtained by administering quite short vocabulary tests – verbal ability is very strongly correlated with adult intelligence (Matarazzo 1972). One such test involves a list of strings of letters, some of which are real words while others are (pronouncable) non-words. Students simply put a tick next to the strings they think are real words. A score is then computed by subtracting the number of non-words ticked from the number of words ticked. (Zimmerman et al. 1977).[6] The approach taken by many researchers in the field is to use of a vocabulary test in conjunction with some other measure, such as SAT scores, or scores on IQ tests. For example, Stanovich and West (1997) used a vocabulary test based on (Zimmerman et al. 1977) in conjunction with self-reported SAT scores. In other studies (1998) they used self-reported SAT scores in conjunction with an adapted form of Set II of the Raven Advanced Progressive Matrices (Raven 1962, Raven et al. 1977) and an adapted form of the Comprehension subscale of the Nelson-Denny Reading Test (Form F, Brown et al. 1981). Klaczynski et al. (1997) used the 40-item vocabulary subscale and the Abstraction subtest of the Shipley Institute of Living Scale (Zachary 1986, Watson et al. 1992).

To discover whether and how critical thinking skills can be improved, we will need to have reliable data on the factors related to individuals' gains on measures of critical thinking. Only then will we know what factors prevent students from getting better at critical thinking and which of these factors can be modified by teaching. The present study has shown that, as predicted by Baron's hypothesis, open-minded attitudes are correlated with gains on at least one measure of critical thinking ability (the CCTST). More research is clearly required to determine what other factors are involved. Cognitive ability seems likely to be one such factor, but to date there seem to have been no studies aimed at verifying this.

A second limitation of the present study is that AOMT was not measured directly. It is unknown whether performance on critical thinking tests such as the GSA and CCTST is correlated with reduced myside or other biases. Indeed, several researchers have suggested that such tests may be something of a blunt instrument when it comes to measuring open-minded, unbiased reasoning skills (Stanovich and West 1997, Baron 1991, Klaczynski et al 1997). Furthermore, although there have been a few studies which suggest that it is possible to reduce biases by teaching or instruction (Anderson 1982, Fischhoff 1975, Arkes 1988, Koriat et al. 1980, Selz 1935, Tetlock 1992, Perkins et al. 1986), these studies have not investigated individual differences associated with these reductions in bias. One way in which the present study could be improved or extended then is by measuring AOMT ability and reasoning biases directly, either in conjunction with, or instead of the standardized critical thinking tests.

The aims of the present study were modest. Due to the lack of a control group, we did not seek to determine whether AOMT ability or dispositions could be improved by our course. Instead, we looked at two questions: whether open-minded attitudes are correlated with performance on critical thinking tests and whether such attitudes are correlated with improvements in critical thinking as measured by such tests. The results obtained provide at least some *prima facie* support for the hypothesis that AOMT can be improved by teaching aimed at changing open-minded thinking dispositions, but clearly a more controlled set of studies needs to be carried out if that hypothesis is to be properly tested. In particular, studies are required that properly control for the effects of maturation (independent of specific

instruction) on open-minded attitudes and critical thinking ability.[7]

However, although we did not have a contemporaneous control group, we can still compare the AOMT version of our course to a version of the same course taught the year before. That course lead to a very slight, but significant increase in critical thinking ability (7.8% on the CCTST and 11.4% on the GSA). The AOMT version of the course did not do significantly better than this (6.6% on the CCTST, 6.5% on the GSA). From an educational perspective, these low average gains are disappointing.

We found some evidence of a ceiling or regression effect that might partly explain these low gains. Our students were of course not selected randomly from the population of all first year university students. They were a self-selected group, who had enrolled in a philosophy course specifically advertised as improving thinking skills. As such, they might be expected to be students who already value thinking and open-mindedness and would therefore score quite highly on the TDQ. For such students, there would not be much room for improvement. And indeed, the mean pre-test score on the TDQ for our students was 72.6%. Furthermore, there was a significant *negative* correlation between TDQ pre-test score and TDQ (absolute) gain scores ($r = -0.455$, $p = 0.015$). This is exactly what would be expected if the subpopulation sampled were near the top end of the population distribution for open-minded attitudes.

We also noted negative correlations between pre-test and (absolute) gain scores on the CCTST ($r = -0.22$, $p = 0.129$) and the GSA ($r = -0.216$, $p = 0.141$). In fact, this was the main motivation for using proportional gain scores when examining correlations between gains and initial open-minded attitudes, since it was expected that proportional gain scores would be independent of pre-test score. This is indeed what we found: the negative correlation between TDQ pre-test and TDQ gain scores was drastically reduced when proportional TDQ gain scores were examined ($r = -0.141$, $p = 0.476$). Likewise for the critical thinking tests: the negative correlations between pre-test and gain scores for the CCTST and GSA completely disappeared when proportional gain scores were used. (For the CCTST, $r = 0.009$, $p = 0.952$. For the GSA, $r = 0.109$, $r = 0.463$). MOVE THIS?

If our students are near the top end of the scale for open-minded attitudes, then it may be quite difficult to detect any improvements in critical thinking ability due to changes in attitude. This may not be the case with younger students (years 10 – 12, for example) or students not enrolled in philosophy subjects. Clearly there is a need to collect more data, to see how open-minded attitudes to thinking are related to age group and to course of study. Where there is more room for improvement in attitudes to thinking, the effect of modifying attitudes on critical thinking gains should be easier to detect.

Finally, it is possible that the lack of any real improvement in critical thinking shown by the class may be due to problems of implementation. Although instruction and exercises designed to improve AOMT skills and attitudes were included in the present course, they were not integral to it. Our course was a more or less standard one, with some AOMT exercises ‘tacked on’. Furthermore, the tutors reported some problems in implementing some of these exercises in the classroom. Studies in the future should attempt to devise and test alternative strategies for improving AOMT and design courses built around the strategies that work best. The aim should be to find activities for students that are both effective and relatively easy to implement.

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Notes

[1] The evidence here is not clear-cut however: other researchers have found no evidence for an association between cognitive ability and bias effects. (Schommer 1990, Kardash and Scholes 1996, Klaczynski and Gordon 1996, Klaczynski 1997, Klaczynski et al. 1997).

[2] The highest such (non-significant) correlation was between age and initial open-minded thinking attitudes (as measured by the TDQ): $r = 0.221$, $p = 0.115$.

[3] See (Hake 1998, Meltzer 2002) for a discussion of the advantages of proportional gain scores over absolute gain scores in the measurement of change. Hake and Meltzer refer to these as 'normalized' gain scores. It should be noted however that Hake and Meltzer's normalized gain scores do not correspond exactly to what we here call proportional gain scores. Normalized gain scores are defined as the ratio of the pre- post-test difference to the maximum possible *gain* that could be earned by a particular student. This does not deal well with negative gain scores. A student with a very high pre-test score (near the test maximum) might well get a slightly lower post-test score as a result of regression effects and measurement error. A normalized gain score for such a student would express this small negative difference as a proportion of how many test points the student could have *gained*, rather than how many test points they could have *lost*. So for example, a student two points from the maximum score on the pre-test who drops one point on the post test would receive a vastly over-inflated normalized gain score of -50%. Proportional gain scores, by contrast, express a loss from pre- to post-test as a proportion of the students' actual pre-test score; that is, as a proportion of how much the student could have lost. So in this example, if the maximum test score was 20, our student would have a proportional gain score of -1/18 = -5.5%

[4] **More details of the AET.**

[5] **Further info. on similarities and differences between these two groups (size, median age, pre-test scores etc)**

[6] Since many students in Australian universities will not have English as a first language, it will be important to determine this for each student and either exclude them from the study or find translations of the tests to be administered.

[7] Although we attempted to recruit a comparison group, to control for changes in attitudes and ability unrelated to specific instruction in AOMT and critical thinking, this has so far had to be on an entirely voluntary basis. Unfortunately, the number of volunteers has been low (16 for the present study) and significant self-selection effects (much higher pre-test scores for example) have been noted.