Humidity, anxiety, and test performance: Maintaining equity in Tropical climates

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Abstract

With the advent of global warming, psychological tests are increasingly administered under high levels of environmental humidity, which may combine with test anxiety to disadvantage millions students worldwide. With temperature held constant, 42 Northern Territory (Australian) undergraduates took basic Digit Span and Stroop tests, under conditions of high/ low humidity and high/ low test rapport (which operationally defined test anxiety). Digit Span performance was significantly depressed both by anxiety and humidity, while Stroop performance was depressed by test anxiety, and marginally affected by an interaction between anxiety and humidity (the latter attenuating negative impact from the former). In the Tropics, the impact of test environment may vary substantially depending on the type of cognitive demands made by the particular assessment task.

In recent years an increasing number of studies have investigated test environment variables that distort mental performance (Gipps & Murphy, 1996), and thereby misrepresent mental competence during academic assessment (Gregory, 1996). However, relatively few studies seem to have explored the impact of more obvious potential threats to test equity, such as the prevailing meteorological and atmospheric conditions. In particular, the effect of humidity on performance has scarcely enjoyed serious investigation, in spite of the fact that three quarters of the world's population live and are tested in Tropical climates (Reading, Thompson, & Millington, 1995).

Environmental Humidity

Test takers who live in Tropical zones may be fortunate enough to undergo assessment in air-conditioned environments. Even there however, the air-conditioning systems often fail, with the result that candidates are rapidly exposed to uncomfortable heat and rising humidity. The limited available research indicates that the impact of high-humidity, while not fully understood, has the potential to significantly lower performance by impairing such mechanisms as (1) short-term-memory and (2) selective attention (Sharma, Pichan, & Panwar, 1983; Howarth & Hoffman, 1984; Sanders & Brizzolara, 1982; Fine, Cohen, & Crist 1960).

Short-term memory performance is essential for basic information processing during any examination (Best, 1995). Selective attention is also a requisite for successful exam performance, allowing the test taker to screen out irrelevant stimuli, for example when required to think laterally (Solso, 1995). Two very well-known tests that often measure these domains, as well as featuring in many test batteries, are the Digit Span (Wechsler, 1981) and Stroop tests (Stroop, 1953), respectively.

Test Anxiety

Test anxiety has been directly linked to poor examination performance (Benjamin, McKeachie, Lin, & Holinger, 1981; Birenbaum & Pinku, 1997; Ikeda, Iwanaga, & Seiwa, 1996; Naveh-Benjamin, McKeachie, & Lin, 1987). Test anxiety refers to physiological, psychological, and behavioural responses that reflect or underpin apprehension about possible failure during a test or evaluative condition (Barlow & Durand, 1995; Calvo & Carreiras, 1993). This factor has been studied and reported in various regions around the world, including the Tropical regions likely to be affected by humidity. Test takers in such regions may not only have climatic extremes to contend with, but also test anxiety. If excessive humidity and test anxiety combine to impair and distort test performance, then individuals living in Tropical climates could be placed at a *double disadvantage*.

Some of the most recent research on test anxiety suggests that there are two types of test anxious students (Birenbaum & Pinku, 1997; Naveh-Benjamin et al, 1987). Some (a) cannot organise and learn the information necessary for recall in examinations, and some (b) suffer from performance-lowering interfering thoughts ("What if I fail?!") during examinations. Research supports both (a) skill deficit and (b) interference models (Tryon, 1980). The former posits that test anxiety is a result of inadequate study behaviours, so performance is low because test takers never actually learn the material to begin with (Culler & Holahan, 1980; Topman & Jansen, 1984). Test anxiety in this case is understood to be the result of not being prepared, rather than a cause of performance decrements per se. The interference model (b) posits that high anxiety produces thoughts and responses that are irrelevant to the task, taking up valuable processing space. These responses compete for processing space and interfere with task-relevant responses necessary for success in evaluative situations. Highly test anxious students are thought to have problems in retrieving the learned information *because* of such maladaptive responses as worry and irrelevant thoughts (Benjamin et al, 1981).

The present study focuses on the population directly affected by test anxiety and interference. This is achieved by testing short-term/working memory rather than long-term memory, which has been shown to be influenced by poor information organization skills (Birenbaum & Pinku, 1997). As no research has been conducted on the effects of test anxiety and humidity *combined*, it is not known what their impact(s) will be on performance. Intuitively, one might assume that two variables that each impact negatively on performance would combine in a simple linear fashion to depress performance even further. Alternatively, the arousal literature (Eysenck, 1985) suggests that the combination of test anxiety (linked to heightened arousal) with humidity (capable of depressing arousal), may shift arousal level closer to its optimum (Howarth & Hoffman, 1984). This combination may therefore help to realign performance levels closer to their optimum (Martens, 1971; Neiss, 1988; Neiss, 1990; Yerkes & Dodson, 1908).

Predictions

Hypothesis 1: With temperature held constant at 28 degrees Celsius (average temperature in tropical climates), high relative humidity (70%-80%/ approximating Tropical Wet Season conditions) will cause participants to perform significantly worse on measures of short-term memory (Digit Span test) and attention (Stroop test) than during low relative humidity (40% - 50%).

Hypothesis 2: Participants in a high test anxiety condition (facilitated by low examiner rapport) will perform significantly worse on measures of short-term memory (Digit Span test) and attention (Stroop test) than participants in a low test anxiety condition (facilitated by high examiner rapport).

Hypothesis 3: There will be an interaction between test anxiety and humidity with optimal performance on Digit Span and Stroop being observed under conditions of high test anxiety (low rapport) and high humidity (Yerkes & Dodson, 1908).

Method

Participants

Participants were 42 undergraduate students enrolled in social science courses at the Northern Territory University (NTU), located in Tropical Darwin. There were 21 males and 21 females ranging in age from 19 - 45 years (mean age = 26 years). This was therefore not a random sample, although allocation to conditions was itself randomised. All participants did take part under conditions of informed consent and confidentiality.

Materials

A standard psychrometer was used to record the humidity immediately prior to the participants entering the room, and immediately after leaving.

A standard split-second chronograph was used to time participants on the Stroop test.

To achieve the desired atmospheric conditions (hot-dry and hot-humid), two humidifiers, a heater, and a dehumidifier, were used. Figure 1 illustrates the positioning of the equipment in the test room. Between testing each participant, a large window was opened for approximately 20 minutes, to prevent the build up of carbon monoxide which could have influenced results (Tucker, 1981).

The Digit Span (Wechsler, 1981) was employed to measure short-term auditory memory and freedom form distractibility (i.e., test anxiety and humidity).

The Stroop Test (Stroop, 1953) was used as a measure of attention and automaticity (MacLeod, 1991).

Figure 1 gives a bird's eye view of the testing room facility, and the placement of key items of equipment within it. Participants were tested in this room individually.

To measure the effectiveness of the anxiety manipulation, we selected 12 items from the Reactions to Tests test, or RTT (Sarason, 1984). These items reflect four interrelated dimensions of test anxiety, namely tension, worry, test-irrelevant thinking, and bodily symptoms. Grammatical tense used in the items was modified from present to past, to fit the post-performance positioning of the RTT items, and the scale was reduced from four to two points (agree/disagree). Two exemplars are, *I felt distressed and uneasy before the tests*, and, *Irrelevant bits of information popped into my head during the test*. A high score on the full 40 items of the RTT is negatively related to performance and positively related to cognitive interference (Sarason, 1984). In our study, with one item deleted due to low item-total correlation, the Guttman Split-half correlation was .82 for the subset of items utilised.

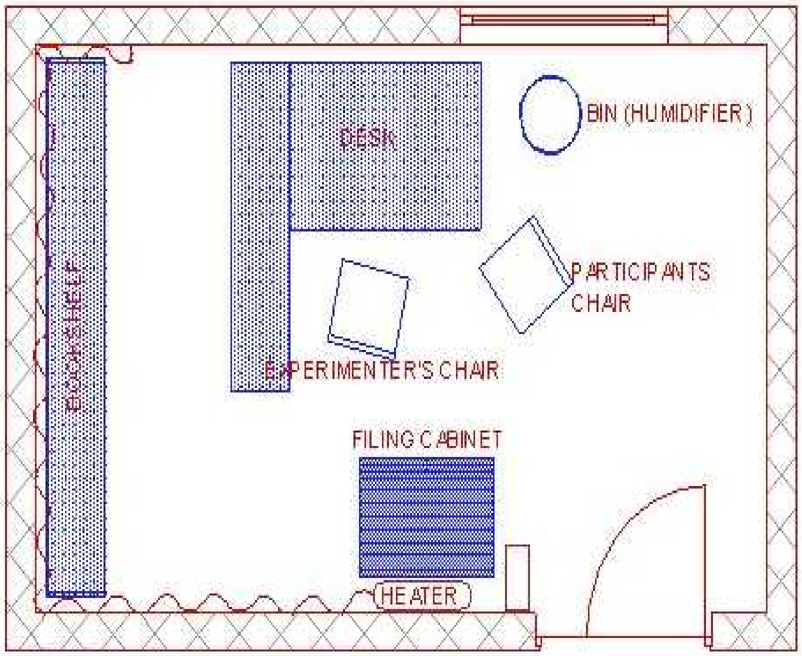

Figure 1
Floor plan of research room

Procedure

In our induced humid conditions, upon entering the research room the participant was met by the experimenter, who apologised for the room's "stuffiness." It was explained that, "the air conditioning has been playing up," which is not a rare occurrence at NTU during the build-up to the Wet season (when the study took place).

For participants in the high test anxiety condition, instructions were given in such a way as to minimise examiner rapport and to that extent heighten test anxiety *beyond its optimum effects for performance* ("both of the tests you're about to take are quite difficult, however the rest of the students so far haven't made many mistakes" [Digit Span]l; and, "the test will be timed so you have to name the colours as fast as you can without making mistakes" [Stroop]). For those in the low test anxiety condition, the instructions aimed to foster examiner rapport and minimise anxiety ("this task starts out reasonably easy and gradually gets a bit harder" [Digit Span]; and, "don't worry about the tasks as they're not too difficult" [Stroop]). In addition, low test anxiety participants received intermittent positive reinforcement during the trials (e.g., "good," "okay," "great").

Order of testing (Digit Span and Stroop) was counterbalanced to minimise any order effects. On completing the tests (no order effects were later found on test scores), participants completed the items from Sarason's (1984) RTT scale.

Results

Scatterplots, observations, and debriefing notes were used to screen the data. Outliers who also behaved unusually (e.g., showed excessive nervousness), and/or those whose circumstances were plainly unusual (e.g., through test familiarity, or heavy outdoor training) were not analysed.

Manipulation Check - test anxiety

A dependent variable was created from summated scores on the RTT scale. Levene's test indicated that variance was not homogenous across conditions (F(1, 40) = 13.021, p = 001). A non-parametric Mann-Whitney test found that the test anxiety manipulation had impact. Participants in the low rapport conditions reported significantly more test anxiety than their counterparts in the high rapport conditions (U = 144.0, N = 42, p =.05).

Digit Span performance

To test the impact of anxiety and humidity, an analysis of covariance (ANCOVA) was computed, with three cases removed using the above criteria. Based on relevant literature regarding acclimatisation (Shapiro, Moran, & Epstein, 1998), amount of time participants had spent in Darwin (or other climatically similar regions, such as North Queensland [Lee & Neal, 1984]), was included as a covariate. It is conceivable for instance that humidity would have less impact on performance for those whom had lived in Darwin for longer. In this study however, length of time spent in Darwin (in months) was not associated with altered performance, F(1, 34) = 2.386, p =.132. Humidity impacted significantly on Digit Span performance, F (1, 34) = 4.674, p =.038, Eta^2 =.121. There was also an effect for anxiety on digit span performance, F(1, 34) 13.90, p =.001, Eta^2 =.290. There was no statistically significant interaction between humidity and anxiety on the Digit Span test, F(1, 34) = 2.26, p =.142. Figure 2 illustrates the detrimental main effects of both high humidity and test anxiety on participants' digit span performance.

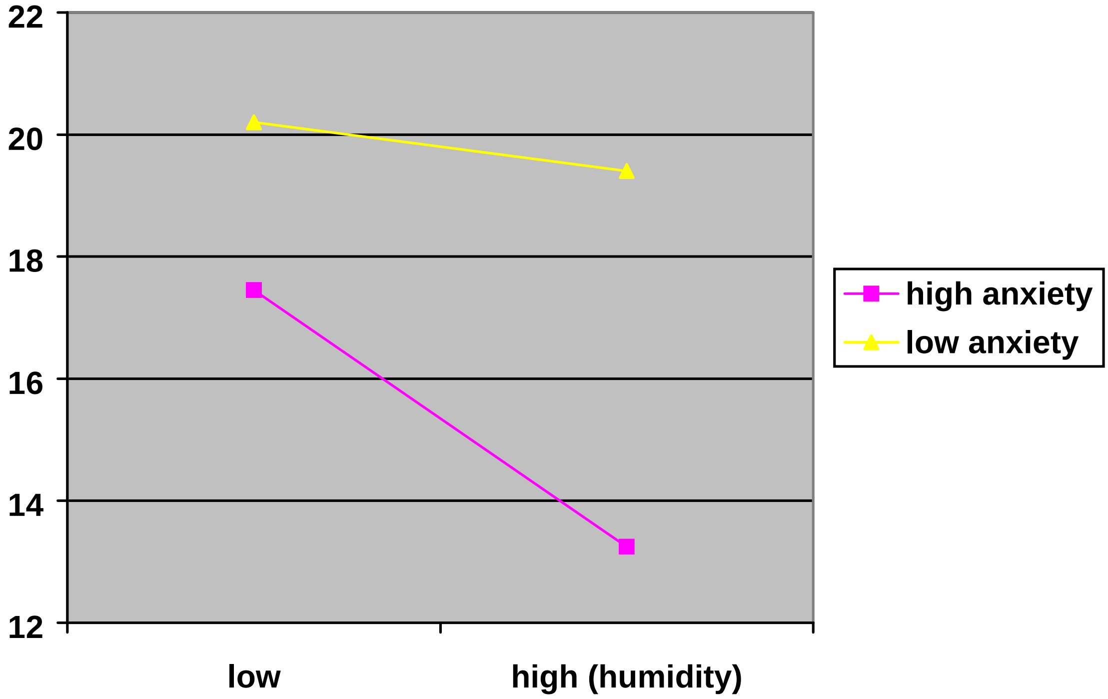

Figure 2
Performance on Digit Span under high and low anxiety and humidity

Stroop performance

To test the effect of anxiety and humidity Stroop performance, an analysis of covariance (ANCOVA) was computed, with four cases removed using the above criteria. Time in Darwin was again included as a covariate. Anxiety impacted significantly on Stroop performance, $F(1, 33) = 4.112$, $p < .05$, $Eta^2 = .111$). From Figure 3, performance was lowest under the high anxiety conditions, particularly when combined with low humidity. Humidity did not have a significant main effect, in itself, on Stroop performance, $F(1, 33) = .009$, $p > .05$. There was a possible significant interaction between anxiety and humidity, $F(1, 33) = 2.732$, $p < .1$, $Eta^2 = .076$). As suggested by Grimm (1993), an alpha of .1 may have been appropriate in this instance, as the area of research (specifically, interactions between humidity and test anxiety) is new. According to Grimm (p. 152), setting a more restrictive alpha may result in prematurely closing off a new research area. Figure 3 depicts the main effect of anxiety, as well as the possible interaction.

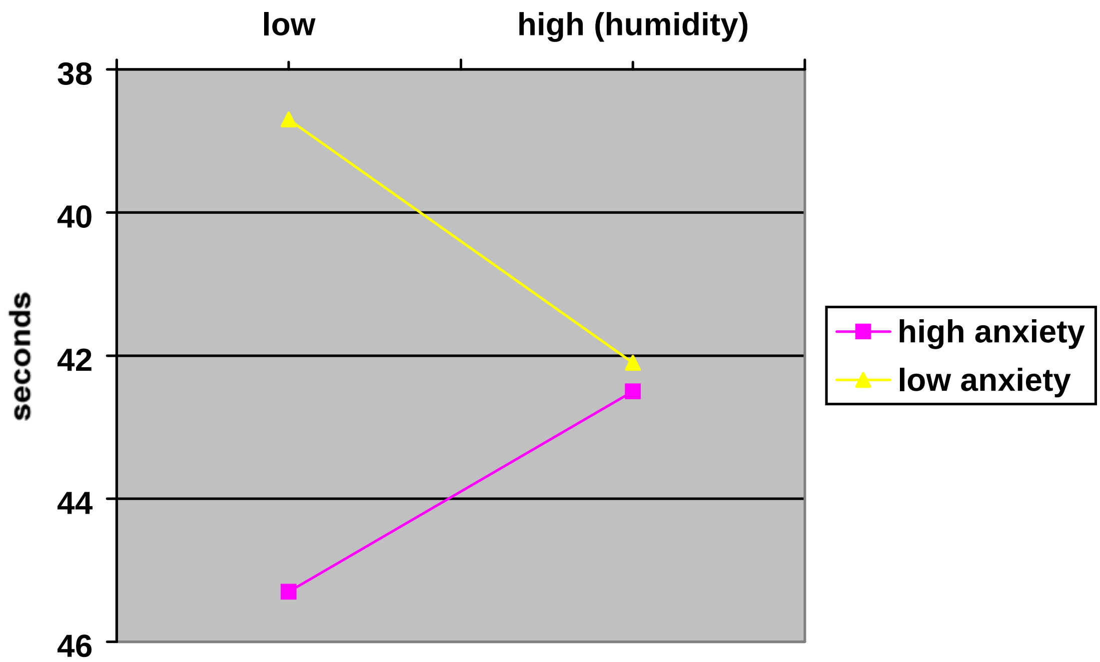

Figure 3
Performance on Stroop task under high and low humidity and anxiety

Discussion

Our hypotheses were differentially supported depending on the dependent variable considered. For the digit span task, both test anxiety and humidity had (additive) main effects, and there was no interaction. For the Stroop task however, high (versus low) humidity seems to have helped the test anxious, perhaps to filter out, or dampen, some of the distracting influences of over-learning (to read words). There was a possible interaction between test anxiety and relative humidity, and our data suggest that this finding might be worth further exploration in future research.

Our finding, that at high levels of humidity performance on the Digit Span test is impaired, converges with the wider literature (Aulociems, 1972; Sanders & Brizzolara, 1982; Sharma et al., 1983; Howarth & Hoffman, 1984). The effect of humidity, on digit span performance, suggests that high levels of humidity can adversely affect short-term memory processes. Even with a small sample size, this effect was detected, suggesting perhaps that the effect on short-term memory is quite resilient. An attenuation model, proposed by Treisman (1960), seems relevant here. It postulates that when humidity is low, people will be able to focus entirely on the digit span task. When levels of humidity are high, cognitive resources are diverted away from the test task, and are given over to coping with the uncomfortable environment. As a result, test performance suffers.

Similarly, our finding that anxiety affects performance converges with the literature previously reviewed, as well as other literature in the field (e.g., Eysenck, 1985; Humphreys & Revelle, 1984; Ikeda et al., 1996).

The interactive results indicated with the Stroop test are broadly consistent with the Yerkes-Dodson law. Optimum performance occurred under conditions of low anxiety and low humidity. Compared to this optimum, a reduction in test rapport may have raised both anxiety and arousal, so that an over-learned response (reading) was socially facilitated (Zajonc, 1965), at the expense of colour-calling (performance criterion). Performance was lowest under these conditions (high test anxiety, low humidity). Compared to those conditions, the heightening of humidity, which is capable of reducing arousal (Eysenck, 1985), may have reduced social facilitation of the dominant response (reading). A problem for this interpretation however is that our effect of humidity on test anxiety was *excitatory* (U = 146.5, N = 42, p = .031, one-tailed). Alternatively, we have seen that humidity can distract and depress concentration (Howarth & Hoffman, 1984). That is perhaps a more plausible explanation of why we detected a possible drop in Stroop performance, among those in the high rapport conditions, as a result of introducing humidity.

Why were the same effects not observed with the digit span task? Digit span performance involves retaining, in Short-term memory, a unique string of familiar numbers. To the extent that these numbers are over-learned to begin with, humidity may negatively facilitate performance on tasks that involve them (Zajonc, 1965). Alternatively, and more likely perhaps, humidity could again distract concentration from the task (Howarth & Hoffman, 1984). In such a context, test anxiety, which Sarason's (1984) scale has explicitly linked to interfering thoughts, would continue to divert the test taker's attention from the task.

According to this interpretation, humidity can function as an unwelcome distracter in one type of task (convergent production, Digit Span) and a welcome distracter in others (because it helps the test anxious to shut out interfering, over-automated routines). In the current study, humidity appeared to partly perhaps "level the [testing] field," rather than tilting it (see Figure 3). The overall point, however, is that environmental conditions may, possibly, have effects that interact in subtle and non-obvious ways to influence test equity.

A possible threat to the external validity of the present research was the clearly "experimental" nature of the tasks. Real tests and examinations have real-life implications for students. Failure may mean repeating the ordeal, or not being accepted into one's desired career course. The two tests given during our study would not have carried such meaning for their takers. As a consequence, we may not have sampled the full range of reactions to test-environmental stressors like humidity and test anxiety. The latter is closely linked, for example, to perceived importance of the test (Gregory, 1996). There would be serious ethical concerns, however, with attempting to "manipulate" this particular variable.

As yet, it is unknown what precise aspects of cognition are affected by humidity and other weather variables. Evidence is lacking for example about whether encoding, recall, or storage processes are differentially affected by humidity. We also do no know to what extent our findings may generalise to people living outside Darwin, where there may be fewer air-conditioning systems per capita. Nor are we able to generalise, on our limited data set, to other cultural groups, for example in Indonesia. Such research may eventually help to identify individuals and groups at risk of inequitable performance decrements due to climatic extremes (including for example those not acclimatised to Tropical regions). In the long run, with the world's climate (including humidity levels) rising rapidly, it may be of global and regional interest to extend "environmental psycho-metrics" to their logical limits. Governments are already taking global climate changes seriously, as indicated by their uptake of the so-called Heat Index. This calibrates the level of bodily discomfort created by both heat and humidity. Our research, although highly tentative and preliminary, begins to suggest that specifically mental discomfort might be critical too.

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References

Auliciems, A. (1972) Some observed relationships between the atmospheric environment and mental work. *Environmental Research, 5,* 217-240.

Barlow, D.H., & Durand, V.M. (1995). *Abnormal psychology: An integrative approach.* Belmont, CA: Brooks/Cole.

Benjamin, M., McKeachie, W.J., Lin, Y-G., & Holinger, D.P. (1981). Test anxiety: Deficits in information processing. *Journal of Educational Psychology, 73,* 816-824.

Best, J.B. (1995). *Cognitive psychology.* Minneapolis, WI: West Publishing.

Birenbaum, M., & Pinku, P. (1997). Effects of test anxiety, Information organization, and testing situation on performance on two test formats. *Contemporary Educational Psychology, 22,* 23-38.

Calvo, M.G., & Carreiras, M. (1993). Selective influence of test anxiety on reading processes. *British Journal of Psychology, 84*, 375-388.

Culler, R.E., & Holahan, C.J. (1980). Test anxiety and academic performance: The effects of study related behaviours. *Journal of Educational Psychology*, *72,* 16-20.

Eysenck, M.W. (1985). Anxiety and cognitive task performance. *Personality and Individual Differences, 6,* 579-586.

Fine, B.J., Cohen, A., & Crist, B. (1960). Effect of exposure to high humidity at high and moderate ambient temperature on anagram solution and auditory discrimination. *Psychological Reports, 7,* 171-181.

Gipps, C., & Murphy, P. (1996) *A fair test?* Milton Keynes, UK: Open University Press.

Gregory, R. J. (1996). *Psychological testing: History, principles, and applications* (2nd edition). Needham Heights, MA: Allyn & Bacon

Grimm, L.G. (1993). *Statistical applications for the behavioural sciences.* Canada: John Wiley.

Howarth, E., & Hoffman, M.S. (1984) A multidimensional approach to the relationship between mood and weather. *British Journal of Psychology, 75,*15-23.

Humphreys, M.S., & Revelle, W. (1984). Personality, motivation, and performance: A theory of the relationship between individual differences and information processing. *Psychological Review, 92,*153-184.

Ikeda, M., Iwanaga, M., & Seiwa, H. (1996). Test anxiety and working memory system. *Perceptual and Motor Skills, 82,* 1223-1135.

Lee, D.M., & Neal, A.B. (1984). The climate of Northern Australia. In Parkes, J. (Ed.), *Northern Australia: The arenas of life and ecosystems on half a continent* (pp 29-55). Newcastle, Australia: Academic Press.

MacLeod., C.M. (1991) Half a century of research on the Stroop effect: An integrative review. *Psychological Bulletin, 109,*163-203.

Martens, R. (1971). Anxiety and motor behaviour: A review. *Journal of Motor Behaviour, 3,* 151-179.

Naveh-Benjamin, M., McKeachie, W.J., & Lin, Y-G. (1987). Two types of test anxious students: Support for an information processing model. *Journal of Educational Psychology, 79,* 131-136.

Neiss, R.(1988). Reconceptualizing arousal: Psychobiological states in motor performance. *Psychological Bulletin, 103,* 345-366.

Neiss, R. (1990). Ending arousal's reign of error: A reply to Anderson. *Psychological Bulletin, 107,* 101-105.

Reading, A.J., Thompson, R.D., & Millington, A.C. (1995). *Humid tropical environments.* Oxford, UK: Blackwell.

Sanders, J.L., & Brizzolara, M.S. (1982). Relationships between weather and mood. *The Journal of General Psychology, 107,* 155-156.

Sarason, I.G. (1984). Stress, anxiety and cognitive interference: Reaction to tests. *Journal of Personality and Social Psychology, 46,* 929-938.

Shapiro, Y., Moran, D., & Epstein, Y. (1998). Acclimatisation strategies: Preparing for exercise in the heat. *International Journal of Sports Medicine, 2,* 161-163.

Sharma, V.M., Pichan, G., & Panwar, M.R. (1983). Differential effects of hot-humid and hot-dry environments on mental functions. *International Archives of Occupational and Environmental Health, 52,* 315-327.

Solso, R.L. (1995) *Cognitive Psychology* (4th ed.). Needham Heights, MA: Simon & Schuster.

Stroop, J.R. (1953). Studies of interference in serial verbal reactions. *American Journal of Psychology, 18,* 643-662.

Topman, R.M., & Jansen, T. (1984). "I really can't do it anyway": The treatment of test anxiety. In H.M. van der Ploeg, R. Schwartzer, & C.J. Speilberger (Eds.). *Advances in test anxiety research.* Hillsdale, NJ: Erlbaum.

Treisman, A.M. (1960). Contextual cues in selective listening. *Quarterly Journal of Experimental Psychology, 12,* 242-248.

Tryon, G.S. (1980). The measurement and treatment of test anxiety. *Review of Educational Research, 50,* 343-327.

Tucker, G.B. (1981). *The CO_2-climate connection: A global problem from an Australian perspective.* Canberra: Australian Academy of Science.

Wechsler, D. (1981). *Manual for the Weshsler Adult Intelligence Scale-Revised.* San Antonio, CA: Psychological Cooperation.

Yerkes, R.M., & Dodson, J.D. (1908) The relation of strength of stimulus to rapidity of habit formation. *Journal of Comparative Neurology and Psychology, 18,* 459-482.

Zajonc, R. B. (1965). Social facilitation. *Science, 149,* 269-274.