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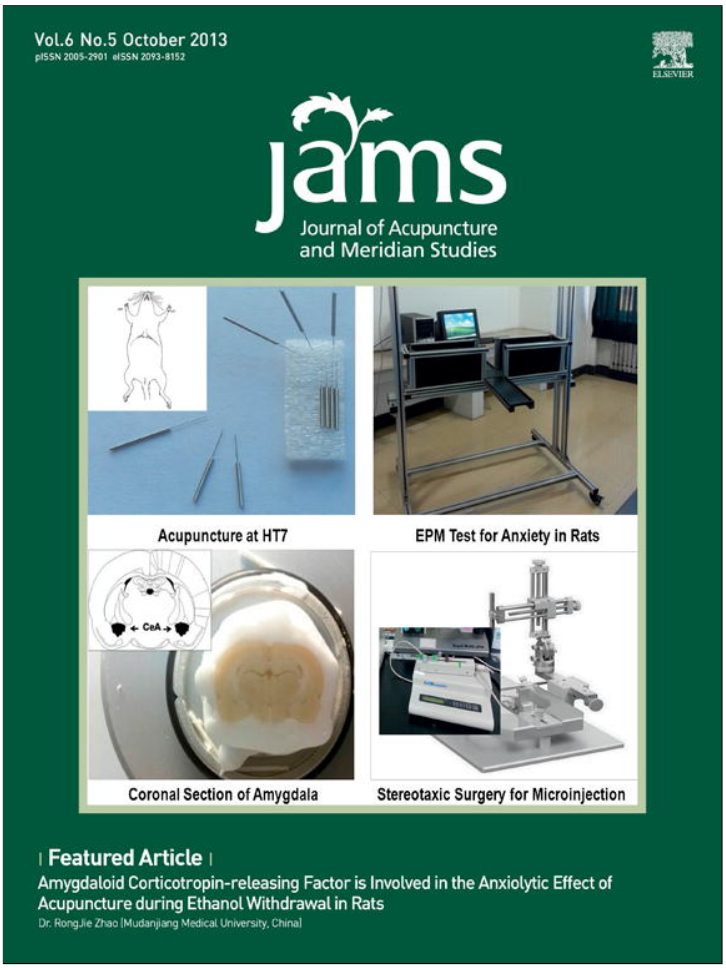

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RESEARCH ARTICLE

The Effect of Acupuncture on Working Memory and Anxiety☆

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KEYWORDS
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Abstract
Objective: The purpose of this study was to investigate whether acupuncture can improve memory and reduce anxiety.
Design, Setting and Subjects: A two-group, randomized, single-blind study involving 90 undergraduate university students was conducted from January to December of 2011.
Interventions: Subjects completed the State-Trait Anxiety Inventory (STAI) form Y-1 (State Anxiety, SA) and Y-2 (Trait Anxiety, TA). Then, each subject lay on a treatment table for 20 minutes. The acupuncture group had needles inserted into select acupoints; control subjects did not. Subjects then completed the STAI form Y-1 again, after which they completed the Automated Operation Span Task (AOSPAN) - a computerized test of working memory.
Main Outcome Measures: Performance on the AOSPAN and the STAI scores were the main measures of the outcomes.
Results: The acupuncture group scored 9.5% higher than the control group on the AOSPAN Total Correct Score (65.39 vs. 59.9, $p=0.0134$), and committed 36% fewer math errors (2.68 vs. 4.22, $p=0.0153$). Acupuncture subjects also reported lower SA after intervention than control subjects (26.14 vs. 29.63, $p=0.0146$).

1. Introduction

Working memory (WM) was originally described by Baddeley and Hitch [1] to account for deficiencies of a model that conceptualized memory as having only long-term and short-term components. WM is short-term memory plus attentional control. It is understood as consisting of three constituent systems: a central executive which is in charge of allocating mental resources and attention; a phonologic

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loop and a visual sketchpad where audio or visual data are kept in short-term memory, respectively [2].

Operation span tasks have been developed to measure WM and have been associated with predicting such diverse capabilities as reading comprehension [3], arithmetic calculation [4], note taking [5], language comprehension [6], learning a computer language [7], learning to spell [8], following directions [9], building vocabulary [10], writing [11], complex learning [12], and reasoning ability [13]. Working memory capacity is correlated with success in many areas.

Anxiety has been shown to impair performance in math [4,14], reading [15], and operation span task measures of working memory [16]. Anxiety impairs test performance. According to the American Test Anxiety Association, "About 16—20% of students have high test anxiety, making this the most prevalent scholastic impairment in our schools today. Another 18% are troubled by moderately-high test anxiety" [17]. This means that up to 38% of students have performance impaired by anxiety. Students with high test anxiety score approximately 12 percentage points lower than their peers on school examinations [18]. Reducing anxiety should help improve test performance.

When performed by a trained practitioner, acupuncture is a safe procedure [19], and has been shown to reduce anxiety. Studies have shown that acupuncture can reduce generalized anxiety, depressive anxiety, and preoperative anxiety. See Pilkington et al [20] for a review of the literature regarding acupuncture and anxiety.

If anxiety impairs memory and acupuncture can reduce anxiety, can acupuncture improve memory? Research has been conducted with cognitively-impaired animals that shows that acupuncture protects and restores cognitive function [21—24]. Some research has also shown that acupuncture can help cognitively-impaired humans [25—27]. To date, however, no study has examined whether acupuncture can improve memory in healthy human individuals. The purpose of this study was to investigate the effect of acupuncture on WM and anxiety in healthy subjects.

2. Material and methods

Full approval for the study was granted by the Institutional Review Board of the National University of Health Sciences. All study protocols adhered to the NIH Guidelines for Protecting Human Research Participants and the Declaration of Helsinki.

2.1. Participants

Ninety students of varied ethnicity were recruited from local universities. Clinical Trial Registry: Clinicaltrial.gov ID = NCT01492738.

Inclusion criteria were that all participants must: be undergraduate university students aged 18—30 years; be willing to receive acupuncture; have not received acupuncture in the three months prior to the testing; be free of any serious medical problems; not be taking any psychoactive medication; not be pregnant; not be breastfeeding; and be fluent in English language. Participants received US$20 financial compensation for their participation at the conclusion of the study.

2.2. Setting

The study was conducted at two private acupuncture clinics: A Center for Oriental Medicine in Wilmette, IL USA, and the Tiffani Kim Institute in Chicago, IL, USA. Consent and demographic questionnaires were filled out in the waiting room. The remaining procedures were performed in a 2.4 m $\times$ 3.0 m private room with a treatment table, a desk with a laptop computer, and one chair.

2.3. Instruments and measures

The state-trait anxiety inventory (STAI) is a self-report anxiety instrument comprised of two separate 20-item subscales that measure state (situational, SA) and trait (baseline, TA) anxiety. The STAI has shown test-retest reliability and external validity [28]. It is one of the most widely-used anxiety measurement instruments in the world [29].

The automated operation span task (AOSPAN) by Unsworth et al is a computerized test of WM that has shown good internal reliability and external validity [30]. Participants are presented with a math problem to perform in their head and then are shown a letter to remember after answering the math problem. Afterwards, they are presented with another math problem followed by another letter. After a set of between three and seven of these math-letter pairs, participants are shown a recall screen and are asked to recall all the letters they were shown in the correct order. The math-letter sets and recall screens are presented consecutively with a total number of 75 letters and math problems each. The AOSPAN absolute score and the total correct score both reflect the recall of the letters. The total correct score counts all correct responses. The absolute score only gives credit for letters recalled correctly when the entire set is recalled correctly. For example, if there is a set of seven math problems and letters and a participant correctly recalls six of the letters, the absolute score would be zero and the Total Correct Score would be six. The AOSPAN also tracks performance on the math problems. It provides a score for the total number of math errors; and breaks that number down into accuracy errors and speed errors (failure to answer in the allotted time) [30]. The AOSPAN can be thought of as testing how well participants can keep information in the back of their minds while processing tasks in the front of their minds and *vice versa*.

2.4. Independent variable

The independent variable was whether or not the participant received acupuncture for 20 minutes while they lay on a massage table for 20 minutes.

2.5. Dependent variables

The dependent variables analyzed were: initial SA (SA1), SA after the variable period (SA2), TA, change from SA1 to SA2 (ΔSA), AOSPAN total correct score, AOSPAN absolute score, AOSPAN math total errors, AOSPAN math speed errors, and AOSPAN math accuracy errors.

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Table 1 Automated operation span task performance by trait anxiety (mean ± standard deviation).

	Absolute	Total correct	Total math errors	Speed errors	Accuracy errors
Low-anxious	50.45 ± 16.74	63.44 ± 9.96	3.19 ± 2.49	0.92 ± 1.26	2.27 ± 1.93
High-anxious	45.68 ± 16.45	60.36 ± 12.99	4.07 ± 3.96	1.25 ± 1.86	2.82 ± 2.75
Difference	−4.77 (9.45%)	−3.08 (4.8%)	+0.88 (27%)	+0.33 (36%)	+0.55 (0.24%)

2.6. Procedure

Participants were randomized into Acupuncture and Control groups. They were tested one at a time and had only one appointment to keep. At the start of the appointment, participants had the study design partially explained to them. Then they completed demographic questionnaire and informed consent forms.

All participants completed STAI forms Y-1 (SA) and Y-2 (TA). After this, all participants were instructed to remove their shoes and socks and lay on a treatment table.

Participants randomized into Acupuncture group then received acupuncture according to Clean Needle Technique at Sishencong (EX-HN1), Shenting (GV24), Yintang (EX-HN3), Shenmen (Ht 7), Neiguan (PC 6), and Taixi (Kd 3). The needles were retained for 20 minutes. After 20 minutes, the needles were removed from Acupuncture group.

Acupoints were selected in an effort to calm the spirit and improve mental function. According to Deadman et al [31]: Sishencong (EX-HN1), benefits the eyes and ears; calms the spirit; and is indicated for poor memory. Shenting (GV24) benefits the brain and calms the spirit. Additionally, the GV channel goes to the brain. Yintang (EX-HN3) calms the Shen and is indicated to calm anxiety and agitation. Shenmen (Ht7) calms the spirit, regulates and tonifies the heart; and is indicated for poor memory, fear and fright. Additionally, the heart organ houses the mind. Neiguan (Pc6) is indicated for poor memory, apprehension, fear and fright. The Pericardium is the protector of the Heart and treats disorders of the spirit. Taixi (Kd3) was chosen because the kidney is associated with the brain and because its low position on the body balances the effect of all the points on the upper body.

The Control group were directed to lie on the same table for 20 minutes. The same acupoints were touched and swabbed with alcohol but no needles were inserted. Care was taken to ensure that the amount of verbal and physical contact was uniform between groups, as Finness et al have shown that differences in these areas can establish a placebo effect and affect outcomes [32]. After this variable period, all participants followed the same protocol.

Participants then completed STAI form Y-1 again and were then directed to a computer where they received instructions for performing the AOSPAN. Participants were instructed that a strong performance on the test would enter them into a drawing for a cash prize and were encouraged to do their best. The researcher remained in the room while participants completed the practice sessions. After the practice sessions, the researcher instructed the participants to complete the AOSPAN on their own. Participants were given a bell to ring and were told, "When you are finished, please ring this bell. Then I will return and we will continue." After the AOSPAN, participants were debriefed.

Care was taken to reduce the likelihood that participants in Control group would realize that they were in Control group. Participants were not told the order of events of the study. They were told, "You'll fill out some self-evaluation questionnaires, take some computerized tests of memory, and may receive acupuncture at some point." When they were administered the AOSPAN, the researcher told them, "Now we will have you take the first memory test." This was intended to raise the possibility in the participants' mind that they could still receive acupuncture before possibly taking another memory test.

2.7. Statistical analysis

Statistical analysis was performed to examine relationships between anxiety, gender, age, and AOSPAN performance. The two-sample *t* test was utilized for statistical comparison of mean values between Acupuncture and Control Groups, and between subgroups. Regression analysis was performed to examine interactions between all measured parameters of STAI and all measured parameters of the AOSPAN.

Table 2 Automated operation span task performance by trait anxiety among control and acupuncture (Acu) groups (mean ± standard deviation).

	Absolute	Total correct	Total math errors	Speed errors	Accuracy errors
LA control (n = 32)	47.59 ± 17.84	61.31 ± 11.53	3.56 ± 2.37	0.91 ± 0.10	2.66 ± 1.94
HA control (n = 14)	41.93 ± 19.59	56 ± 15.99	5.71 ± 4.92	2.0 ± 2.35	3.71 ± 3.47
Difference	−5.96 (11.8%)	−5.31 (8.6%)	+1.86 (60.4%)	+1.09 (120%)	+1.05 (39.5%)
LA Acu (n = 30)	53.50 ± 15.19	65.70 ± 7.50	2.80 ± 2.59	0.933 ± 1.51	1.87 ± 1.87
HA Acu (n = 14)	49.43 ± 12.15	64.71 ± 7.35	2.43 ± 1.60	0.5 ± 0.65	1.93 ± 1.38
Difference	−4.07 (7.6%)	−0.99 (1.5%)	−0.37 (13.2%)	−0.4.3 (46%)	+0.06 (3.2%)

HA = high-anxious; LA = low-anxious.

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Table 3 Automated operation span task performance gender differences (mean ± standard deviation).

	Absolute	Total correct	Total math errors	Speed errors	Accuracy errors
Female ($n = 52$)	49.12 (±16.84)	62.71 (±10.26)	2.96 (±2.32)	0.78 (±0.89)	2.17 (±1.89)
Male ($n = 38$)	48.76 (±16.75)	62.16 (±12.10)	4.16 (±3.72)	1.34 (±1.98)	2.82 (±2.59)

Total math errors male vs. female $p = 0.0638$.
Math speed errors male vs. female $p = 0.0772$.

3. Results

Ninety students met inclusion criteria and participated. Control group had 46 participants (22 males, 24 females) and a mean age of 21.28 years. Acupuncture group had 44 participants (16 males, 28 females) and a mean age of 20.53 years. There were no significant differences in gender makeup, age, or handedness between groups. There were no adverse reactions reported from any participants. Results are presented as mean ± standard deviation and confidence interval (CI).

3.1. STAI

The STAI yielded numeric values for: initial state-level anxiety (SA1), Trait level anxiety (TA), and state-level anxiety after variable period (acupuncture or rest, SA2). The difference between SA1 and SA2 was termed ΔSA.

There were no significant differences in SA1 or TA between groups. Mean SA1 was 35.98 ± 7.26 (95% CI 35.9—36.04) in the Control group and 33.75 ± 7.14 (95% CI 33.68—33.82) in the Acupuncture group ($p = 0.146$, not significant). Mean TA was 38.46 ± 10.6 in the Control group (95% CI 38.35—38.55) and 37.86 ± 10.39 (95% CI 37.76—37.86) in the Acupuncture group ($p = 0.789$, not significant). Mean ΔSA was −6.35 ± 7.49 (95% CI 6.23—6.37) in the Control group and −7.61 ± 5.65 (95% CI 7.54—7.64) in the Acupuncture group ($p = 0.33$, not significant). The mean SA2 was 29.63 ± 8.2 (95% CI 29.55—29.71) in the Control group and 26.14 ± 4.5 (95% CI 26.09—26.17) in the Acupuncture group ($p = 0.0146$, significant).

The values obtained for TA ranged from 23 to 63. Using a median split, participants with TA below 43 were classified low-anxious (LA, $n = 62$) and those with TA at or above 43 were considered high-anxious (HA, $n = 28$). Within the Acupuncture group, the reduction in SA was greater for those considered to be HA (9.93 ± 6.40, $n = 14$; 95% CI 9.82—10.02) compared to those considered LA (6.53 ± 5.02, $n = 30$; 95% CI 6.47—6.59), but this was not quite statistically significant ($p = 0.0623$).

3.2. AOSPAN

The AOSPAN provided numeric values for absolute score, total correct score, total math errors, math accuracy errors, and math speed errors. The highest possible absolute and total correct score was 75.

Participants who received acupuncture performed better than the Control on the AOSPAN. For the total correct score, participants in the Acupuncture group scored 9.5% higher than those in the Control group [65.39 ± 7.38 (95% CI 65.32—65.46) compared to 59.70 ± 13.1 (95% CI 59.58—59.82), $p = 0.0134$, significant]. The mean AOSPAN absolute score was 45.87 ± 18.36 (61.2% correct; 95% CI 45.70—46.04) in the Control group and 52.20 ± 14.28 (95% CI 52.07—52.33) in the Acupuncture group ($p = 0.072$, approaching significance). For the subgroup of males, AOSPAN Absolute score was 44.14 ± 16.73 (58.9% correct; 95% CI 44.36—44.92) in the Control group ($n = 22$) and 55.13 ± 15.01 (95% CI 53.37—54.89) in the Acupuncture group ($n = 16$, $p = .044$, significant). The Acupuncture group committed 36% fewer math errors. The mean total number of math errors was 4.22 ± 3.44 (95% CI 4.19—4.25) in the Control group and 2.68 ± 2.31 (95% CI 2.66—2.70) in the Acupuncture group ($p = 0.0153$, significant). The mean number of math speed errors was 1.24 ± 1.59 (95% CI 1.23—1.25) in the Control group and was 0.80 ± 1.3 (95% CI 0.79—0.81; $p = 0.153$, not significant). The mean number of math accuracy errors was 2.98 ± 2.52 (95% CI 2.96—3.00) in the Control group and 1.89 ± 1.71 (95% CI 1.87—1.91) in the Acupuncture group ($p = 0.0188$, significant).

Regression analysis was performed and no significant correlations were found between: gender and anxiety (SA1, SA2, TA, ΔSA); gender and performance on all measures of the AOSPAN; TA and AOSPAN performance; SA2 and AOSPAN

Table 4 Automated operation span task performance gender differences among control and acupuncture (Acu) groups (mean ± standard deviation).

	Absolute	Total correct	Total math errors	Speed errors	Accuracy errors
Female control ($n = 25$)	47.46 ± 19.97	60.58 ± 12.62	3.04 ± 2.26	0.83 ± 0.70	2.21 ± 1.93
Female Acu ($n = 27$)	50.54 ± 13.84	64.54 ± 7.48	2.89 ± 2.41	0.75 ± 1.04	2.14 ± 1.88
Difference	+3.08 (6.4%)	+3.96 (6.5%)	−0.15 (−4.9%)	−0.08 (9.6%)	−0.7 (3.2%)
Male control ($n = 22$)	44.14 ± 16.73	58.73 ± 13.83	5.5 ± 4.07	1.68 ± 2.12	3.82 ± 2.84
Male Acu ($n = 16$)	55.13 ± 15.01	66.88 ± 7.21	2.31 ± 2.15	0.88 ± 1.71	1.44 ± 1.31
Difference	+10.99 (24.9%)	+8.15 (13.9%)	−3.19 (58%)	−0.80 (47.6%)	−2.38 (62.3%)

Absolute score for male control vs. male Acu; $p = 0.0442$.

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performance; SA1 and ΔSA; or between ΔSA and AOSPAN performance.

Overall, a trend occurred where participants with HA performed worse on the AOSPAN than LA participants. When broken down into Control and Acupuncture groups, HA participants performed below the LA participants in the Control group; but this detriment was reduced or eliminated in the Acupuncture group (Tables 1 and 2). There was also a trend that the improvement in scores on the AOSPAN found in the Acupuncture group was more pronounced for males than for females (Tables 3 and 4).

4. Discussion

This protocol improves memory and decreases anxiety immediately after administration. Participants who received acupuncture scored 9.5% higher as a total correct score and committed 36% fewer math errors. This technique also reduced anxiety. However, improvement in memory was unrelated to SA and ΔSA.

4.1. HA/LA differences

This research also supports the existing evidence that HA individuals do not perform as well as LA on tests of working memory [14,33,34]. In all categories that AOSPAN measures, HA individuals scored lower than their LA counterparts did, although this was not statistically significant (Tables 1 and 2). The use of the median split has been questioned by Conway et al [35] and there are some limitations to this procedure. The median split still is widely used with the STAI and yields a thought-provoking trend in this case. The administration of acupuncture reduced some of the deleterious effects of HA. When broken down between Control group and Acupuncture group, the effect of HA was much less for those who received acupuncture.

4.2. Gender differences

Although sample size of each gender was not large enough to reach conclusions that are statistically significant, an interesting trend emerged in the analysis (Tables 3 and 4).

There were no significant gender differences in STAI data. However, when examining AOSPAN performance, the benefits of acupuncture were more pronounced for males than for females. Males without acupuncture performed worse than females without acupuncture on every measure of the AOSPAN. With acupuncture, males performed better than females on every measure except math speed errors.

The AOSPAN absolute score was 6.4% better for females in the Acupuncture group vs. females in the Control group, but the score was 24.9% higher for Acupuncture males vs. Control males. Acupuncture helped females perform 6.5% better as a total correct score; and acupuncture improved males' performance by 13.9%. Females who had acupuncture made 4.9% fewer total math errors than females in the Control group; Acupuncture males made 58% fewer total math errors than the Control male group. These differences are not statistically significant and may disappear in a larger sample. However, if the trend is valid, the author has no explanation regarding why males benefit more from acupuncture than females do. It could be that the deleterious effects of anxiety are more pronounced in males; therefore, reducing anxiety has a greater benefit to them. However, since these differences are not statistically significant, it could just be random chance that accounts for these trends. Future study is needed to investigate gender differences in acupuncture and WM further.

4.3. Alternative research designs

An alternative design for this study would be to have participants take the AOSPAN before and after the variable period. For this study, this design was rejected because it was felt that taking the test twice measures participants' ability to learn a task rather than solely testing memory. Additionally, no data exist testing the reliability or the validity of the AOSPAN's measurement when administered twice in such a short time span.

This study indicates that acupuncture can improve memory and reduce anxiety in the short-term. Future study should investigate how long these effects last.

4.4. Why no sham (placebo) group?

Sham acupuncture does not exist. Placebo acupuncture is not an inert intervention. The two most common methods for administering sham acupuncture are cutaneous stimulation/superficial needling or needling points away from major (or indicated) acupuncture points, also known as "off-site" needling.

Superficial and off-site needling have been shown to induce physiologic changes in the limbic system; and those changes are different between participant types. For example, superficial needling increases limbic system activity in participants who have no pain, but it reduces it in those with pain. Some studies have shown that sham acupuncture is as effective as verum acupuncture, and that both are more effective than placebo medication. Others have shown the addition of both verum and sham acupuncture to medication provide superior benefit over medication alone, but the addition of verum acupuncture is more beneficial than sham. Others have shown that, while both sham and verum may be beneficial, they may work through different mechanism. Some studies even have concluded that sham acupuncture is more effective than verum, and that both are more effective than no treatment [36]. Clearly, these techniques are not inert.

Lundeberg et al reviewed the literature regarding "placebo" acupuncture and concluded that it does not serve to elucidate acupuncture's effects but rather introduces a potential bias, which interferes with understanding its true effects [36].

Did the participants in the Acupuncture group know that they were in the treatment group? Yes. Did those in the Control group know that they were in the Control? No, they were unaware of study protocol and did not know until the end that they were not going to receive acupuncture. It is possible that participants in the Acupuncture group's knowledge that they had received an intervention may have boosted their confidence and, therefore, their

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performance. For this reason, future research may incorporate a placebo pill group so that all participants would believe they had received an intervention prior to taking the AOSPAN and the STAI for the second time. All participants were told that a strong performance on the AOSPAN would enter them into a drawing for a cash prize, so it is assumed that all participants gave their best effort.

5. Conclusion

This acupuncture protocol improves memory and reduces anxiety, but those effects are not correlated.

Disclosure statement

The author affirms there are no conflicts of interest and the author has no financial interest related to the material of this manuscript.

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