

# Improving Visio-Motor Coordination in Non-Dominant Hands through Tracing Tasks

by

Zachary M. Eisenstat

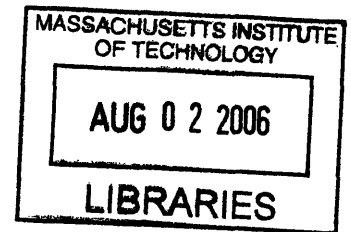
Submitted to the Department of Mechanical Engineering in Partial Fulfillment of the Requirements for the Degree of

Bachelor of Science

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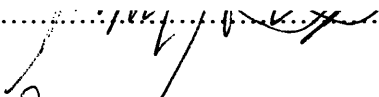
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June 2006

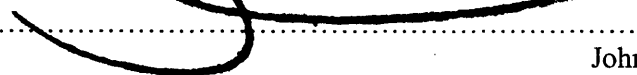


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## **ABSTRACT**

Visuo-motor skills are essential in the performance of various everyday tasks. These skills can be impaired in several neurological conditions. Effective rehabilitation schemes are needed in order to improve visuo-motor coordination in such subjects. This study will propose and test a training regimen as a potential approach for improving fine eye-hand coordination. It will also seek to understand the significance of feedback in visuo-motor improvement. We tested three groups of subjects: those who received training with feedback, those who received training without feedback, and a control group that received no training. The results indicate the effectiveness of our training routine and also highlight the importance of feedback in improving eye-hand coordination.

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## **Introduction:**

Visuo-motor coordination involves the use of visual information to control physical movement. It is an important skill that allows individuals to successfully function in a wide array of tasks. Effective visuo-motor coordination is necessary when driving a car, hitting a baseball, picking up food, playing videogames, or doing any number of other activities.

Through natural development and constant use, visio-motor skills are improved and perfected. However, it remains unclear whether significant improvement can be achieved in adulthood and precisely what kinds of activities might result in improvement. We shall explore both of these questions in this thesis.

An important dimension along which to probe the second issue (and implicitly the first) is that of feedback. One possibility is that utilizing the visuo-motor system, in any situation will help to improve its effectiveness. Another possibility is that the visuo-motor system is improved more when feedback is available. This would mean that the act of constantly correcting to obtain a desired result would be an essential factor in strengthening the visuo-motor system.

By assessing the improvement of individuals before and after a training task that involves or does not involve feedback, this study will attempt to better understand the role of feedback in visuo-motor improvement. It will also attempt to explore the overall feasibility of fine-visuo-motor skill training in adulthood.

A benefit from uncovering an effective training method for fine visuo-motor skills is its use on individuals with impaired ability. Visio-motor ability is susceptible to many forms of deterioration and developmental impediments. This can be caused by visual or muscular impairment, or through inactivity.

Non-dominant hands are often not used for performing fine motor skills like writing or drawing. This lack of natural practice and improvement in the non-dominant hand provides us an excellent opportunity to examine the questions mentioned above in otherwise normal adults. To assess these two factors, feasibility and feedback importance, this study will look at the improvement of right-handed individual's left-hand tracing proficiency. The low level of proficiency will not only allow for greater improvement, but will also eliminate a great deal of

the unintentional training that might occur during the testing period if it were the dominant hand being tested.

We expect that our results will highlight the importance of feedback in the learning process and might also yield applied benefits in terms of suggesting a practical and effective system to assess and develop visio-motor abilities.

## **Background:**

Considering the fundamental nature of the issue, it is perhaps not surprising that a rich body of work has accumulated, investigating the neurological underpinnings of the highly complex interaction of visual information and physical action. The visuo-motor transformations seem to be specific to various types of hand-eye movements (Crawford, et al. 2004). For instance, fine-hand-eye coordination in rhesus monkey is correlated with saccadic eye movements that center on specific points of a drawn curve. These fixation points vary with changing hand position, suggesting eye positioning is set to best benefit hand positioning (Reina and Schwartz, 2003).

It is interesting to consider the specific stages in the developmental progression of hand-eye coordination. Visually directed grasping has been found to really begin developing during the fifth month of life. Infants are observed making slow hand movements toward objects with frequent visual focus shifting between their hand and goal. They are also noted to begin making attempts at grasping the objects they reach for. Two factors have been found to be critical to this development: the natural physical motion of the child and the existence of visually stimulating environmental objects that can provide varying information dependent on the infant's movements (White, Held, and Castle 1967). The visuo-motor system is found to be extremely plastic during the early stages of the developmental process. This has been shown as greater environmental stimulation results in faster reaching development during infancy (White, Held 1967). Finally, at age eight, reaching task accuracy and reaction time are found to be consistent with adult results. Between the ages of six and seven there is a significant reduction in reaction time in this eye-hand coordinated task. Also, between seven and eight there is a significant increase in accuracy (Favilla, 2005).

The development of visuo-motor control has been shown to have a dependence on feedback (White, Held, Castle, 1967). The visuo-motor system is likely making assessments to best execute visuo-motor activity through internal predictions of outcomes with real-time sensory feedback (Vaziri et al., 2006). Progressions in adult eye-hand coordination have been observed, at least for novel tasks. The first stage of learning shows eye movement following the physical affected stimuli. This is to understand the effects of hand movement in this environment. The second stage shows that visual attention begins to anticipate movement, allowing vision to assist in more accurate and faster responses. Finally, the third stage shows that participants merely need to look at their goal to achieve successful motor-movement (Sailer et al. 2005). While this study does not necessarily show much about the development of the visuo-motor system, it offers insight into how a developed system learns a novel task. The results of this study suggest the importance of feedback, specifically in the first, and most substantial stage, of learning.

While a significant body of work exists concerning benefits of training, for both non-clinical, and clinical individuals, there is little work concerning the actual effects of feedback (Reina and Schwartz, 2003; Sailer et al., 2005). The present study will seek to begin answering the question of the importance of feedback and its place in visuo-motor improvement. Is movement in response to reference patterns enough to improve eye-hand coordination in fine motor activities, or is persistent feedback essential to this process? The fine-visuo-motor task used in this study will attempt to test both the feasibility of visuo-motor skill improvement and also the significance of feedback.

## **Methods:**

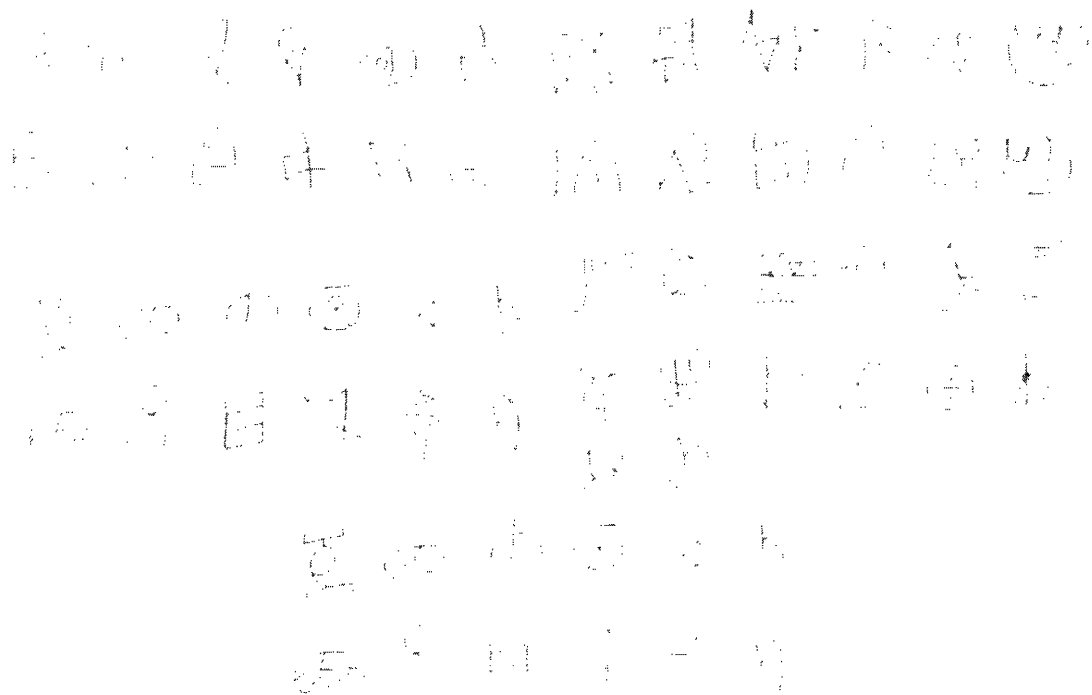
### **Participants:**

Thirty college students were selected to participate in the study. They consisted of fourteen (14) females and sixteen (16) males. Every individual was asked whether or not he or she was right handed. Any individuals who responded that they were not, or that they were

ambidextrous, were not included in our group of participants. They were also asked if they frequently used their left hands for any fine-motor tasks. This ensured that the subject population was all right-handed and had little to no left-handed writing or drawing practice.

**Stimuli:**

We used a large collection of letters drawn from several alphabets. The alphabets were chosen so as to span a wide range of letter appearances (curved and straight strokes, varying degrees of letter complexity), and also to be unfamiliar to typical participants in the US. Some of our stimuli are shown in figure 1.



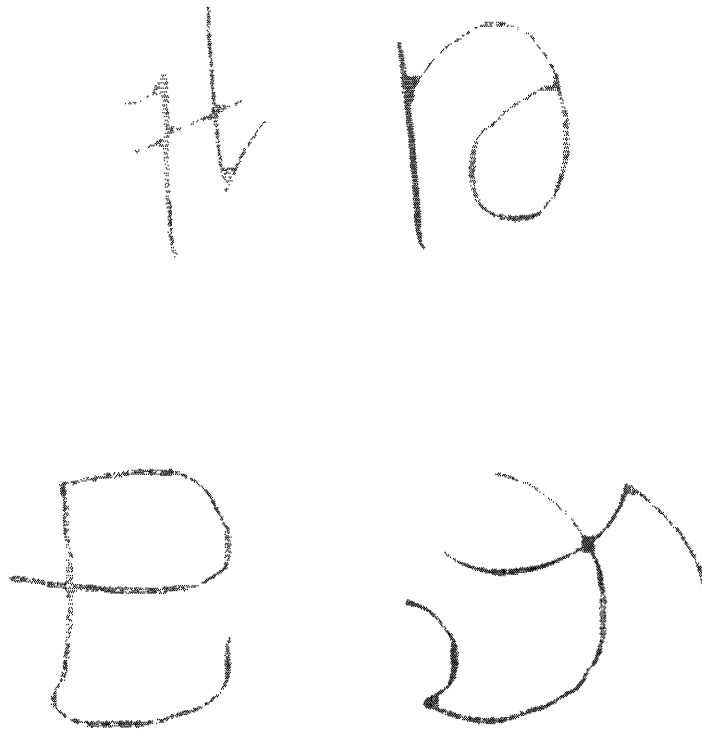
**Figure 1: Stimuli used in pre- and post-assessment test.**

**Procedure:**

Every participant was administered two pre-training tests. The first test was composed of fifty unique letters. They were asked to report any images which were familiar to them. Only one person noted recognizing a letter. With a red felt marker, they were asked to trace the images (fig.2) on the page with their left hand. They were also asked to spend no more than two to three seconds on each image. While minor variations in time were noticed, no subject finished in more than five minutes or less than three minutes.

The reason for instituting a time constraint was to prevent wide discrepancies between subjects. Also it prevented subjects from adopting unusual strategies (such as very deliberate and slow movements) with their left-handed tracing.

After tracing with their left hand, participants were given the second pre-training test. This consisted of the same images, in the same order, as the first test. They were again asked to trace the images with a red felt pen, though this time with their right hand. Before beginning they were informed to only spend two to three seconds on each image.



**Figure 2: A sample page from the assessment test**

Following the two pre-training tasks, subjects were randomly split into three equal-sized groups of ten people each.

**Group1 (Subjects received feedback):**

These participants were given a packet of seventy pages with four images on each page. The packet was pre-divided into seven sections of ten pages each. Participants were then told to practice on ten pages per day. Each of the two-hundred-and-eighty images were unique. They were informed to only use their left-hand and the red felt marker that they were given during the



pre-training test. Aside from this, they were told to avoid any excess training or left-handed activity. They were also informed that they would be tested again after their week of training.

**Group2 (Subjects not given feedback):**

These participants were given the same packet as those in group 1. The only different instruction that they received was that they were to use the back of the pen they received to trace the images. This meant that no marks were left on the page when they were drawing over the figures.

**Group3, Control:**

This was the control group. They were given no training packet or task. They were informed that they would be tested again after seven days.

At the end of the training week every participant was asked back. They were then given the same fifty images with which they were originally tested. Every individual was then asked to trace the letters with their left-hand. Again they were informed to only take two to three seconds on each image.

**Data:**

**Metric of tracing proficiency:**

In order to quantitatively assess how well a subject was able to trace a given reference curve, we used a metric based on the number of crossings of the drawn curve and the reference curve. Two curves that are exactly alike and perfectly superimposed will yield a metric value of 0 while curves that are imperfect copies will result in multiple intersections, and therefore a high metric value.

**Effectiveness of Training:**

To calculate the effectiveness of the training program for improving eye-hand coordination, the results of the pre-training left-hand assessment test were compared to the post-training

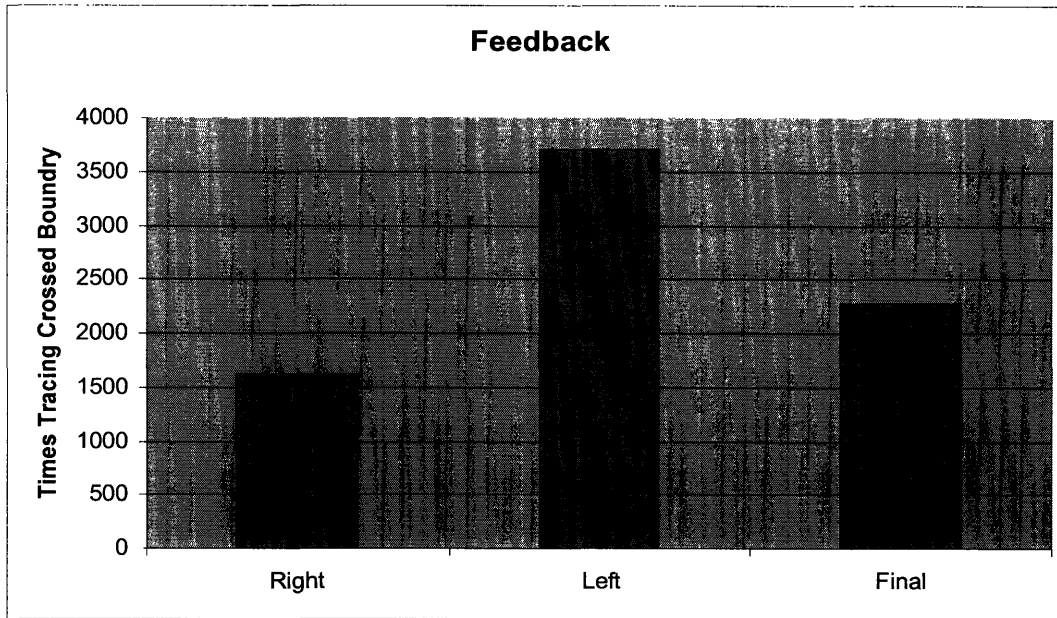
assessment test for each individual. With this information, a one-tailed paired t-test was used to determine if there was a significant level of improvement in the groups that received training and the control group.

**Training with Feedback:**

	Right	Left	Final	(Final-Left)
1	95	277	255	-22
2	68	270	199	-71
3	263	405	331	-74
4	106	280	191	-89
5	101	352	256	-96
6	299	333	195	-138
7	214	418	262	-156
8	117	450	231	-219
9	186	446	208	-238
10	179	480	147	-333
Total	1628	3711	2275	-1436

**Table 1: Results of the Feedback group's assessment tests**

The ten participants who received feedback had the largest reduction in tracing mistakes between the left-handed pre-training assessment test and the post-training assessment test. The pre-training test analysis showed that they had traced beyond the boundaries 3,711 times. The post-training test showed only 2,275 marks outside the tracing images. Also, in line with expectation, the right-handed assessment had the fewest errors with only 1,628.



**Table 2: Graph of the Feedback group's results**

The paired t-test resulted in a t score of -4.79 and the standard deviation of the difference was 94.8. With 9 degrees of freedom, this points to a one-tailed P value of 0.00049. This highly significant result suggests that there is an improvement in left-handed tracing proficiency between the two assessment tests for the feedback group. The 95% confidence interval for the mean is -211.4 to -75.82.

Also noticeable in the data is that every subject in this group improved on their pre-training assessment score. This improvement ranged from 22 to 333 fewer marks beyond the boundaries.

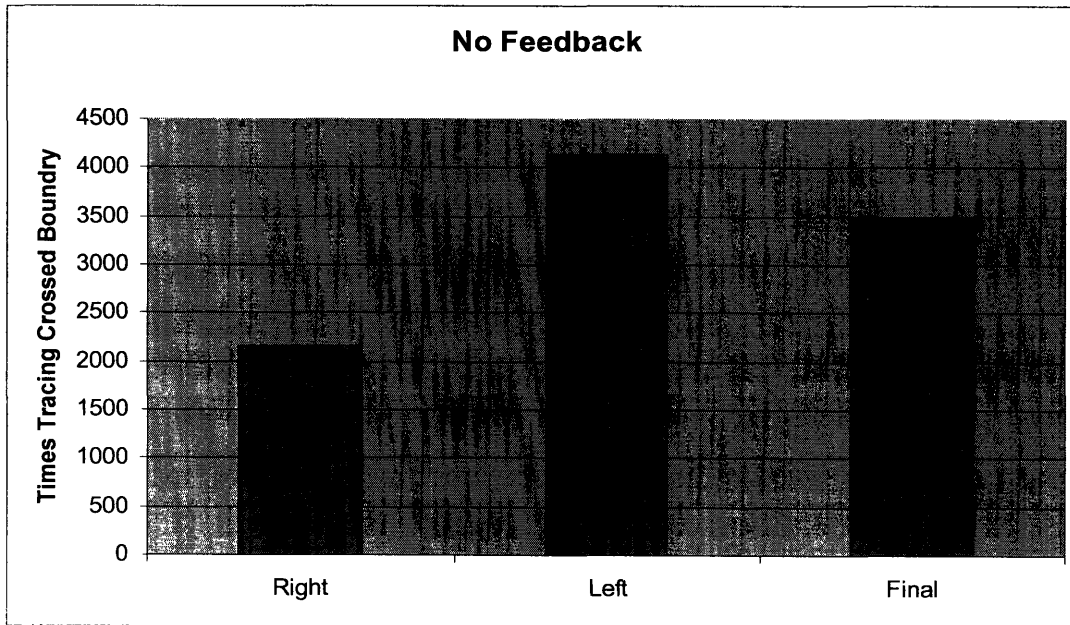
**Training without Feedback:**

	Right	Left	Final	(Final-Left)
1	216	253	359	106
2	227	269	335	66
3	177	405	378	-27

4	187	370	333	-37
5	180	397	347	-50
6	196	501	447	-54
7	253	384	315	-69
8	236	478	339	-139
9	140	531	339	-192
10	342	547	304	-243
Total	2154	4135	3496	-639

**Table 3: Results of the Non-Feedback group's assessment tests**

The non-feedback group showed less drastic improvement between the left-handed initial assessment and final assessment. The original test, across all the members of this group, had 4,135 marks outside the specified tracing regions. This improved to a total of 3,496 in the post-training test. The improvement between the two tests was 639, about 44.5% less than the progress seen in the feedback group. Again, the right-handed assessment had fewest deviations with only 2,154 incorrect lines.



**Table 4: Graph of Non-Feedback group's results**

The t-test resulted in a t-score of -1.90 and 9 degrees of freedom. This correlates to a one-tailed P value of 0.0453. Also, the standard deviation between the groups was 107. The 95% confidence mean is between -140.2 and 12.36. While there is an observable improvement in tracing errors between the pre- and post-test, an additional t-test comparing results across groups 1 and 2 shows that there is noticeably more improvement in the feedback group (The calculated t-score was -1.77, and with 18 degrees of freedom it yielded a P value of .0471).

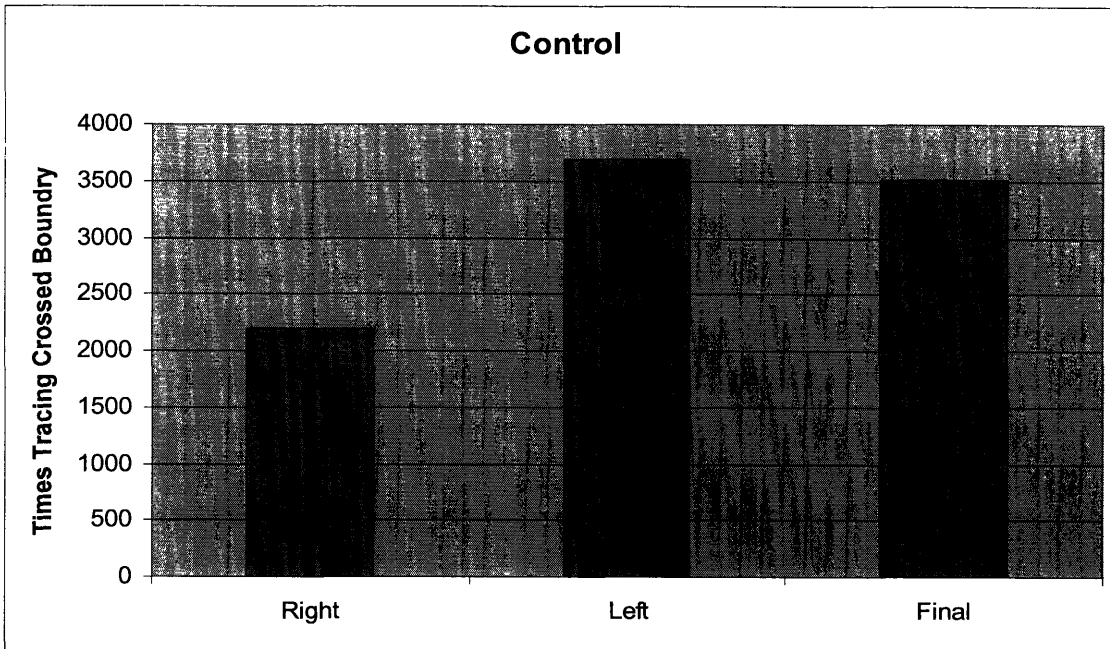
In group 2, only two participants did not better their pre-training score on the final assessment. One individual made 66 more errors and another made 106 more. Although two did not improve, the progress of the other participants ranged from 27 to 243 fewer inaccurate tracing lines.

**Controls:**

	Right	Left	Final	(Final-Left)
1	254	210	315	105
2	192	408	472	64
3	158	277	336	59
4	216	449	498	49
5	199	362	350	-12
6	264	404	373	-31
7	173	347	314	-33
8	276	391	308	-83
9	306	394	281	-113
10	160	447	259	-188
Total	2198	3689	3506	-183

**Table 5: Results of the Control group's assessment tests**

The ten controls, receiving no training between their pre-training and post-training assessment, were analyzed. Their initial test showed that they had drawn beyond the tracing boundary 3,689 times. This was 183 more times than the 3,506 times they traced beyond the boundaries in their final test. They were far more efficient with their right hands, as was expected, making only 2,198 marks outside the specified regions.



**Table 6: Graph of Control group's results**

The t-test of their data yielded expected results. Comparing their left-handed tracing abilities pre- and post-training showed a t-score of -0.635, with a standard deviation of 91.2 and 9 degrees of freedom. This meant that the one-tailed P value was 0.271. At the 0.01 level, this is not significant. Also, the 95% confidence interval for the mean is between -83.54 and 46.94. These results suggest that there is likely no improvement in the control group's left-handed tracing ability between the pre-test and post-test.

While there was an improvement in some of the control's assessment scores, 40% had an increased number of deviations from the tracing boundaries. The range of improving scores was between 12 and 188 fewer deviations, and the range for increasing number of deviations ranged from 49 to 105.

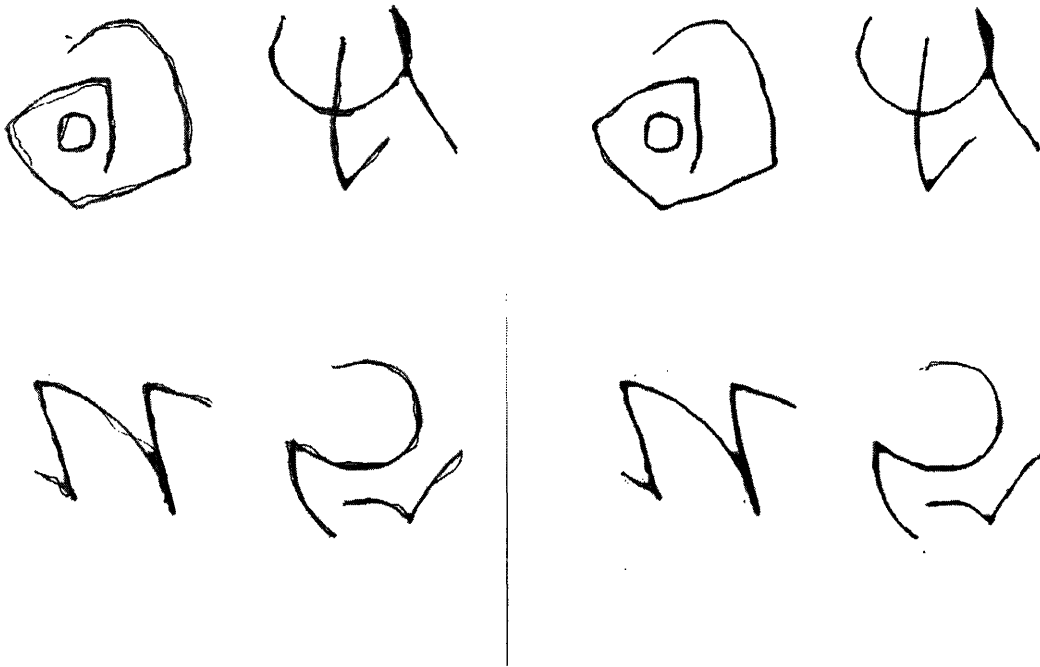
To test whether or not the improvement of group 1 and group 2 was significantly greater than for group 3, two t-tests were performed. The t-test between group 1 and group 2 yielded a t-score of -3.01 with 18 degrees of freedom and a P value of 0.00347. This result is highly significant and suggests that group 1's reduction in mistakes is greater than group 3's. Alternatively the results for group 2 versus group 3 returned a t-score of -1.03 with 18 degrees of

freedom and a P value of 0.159. This implies that group 2's improvement is not significantly different than group 3's improvement.

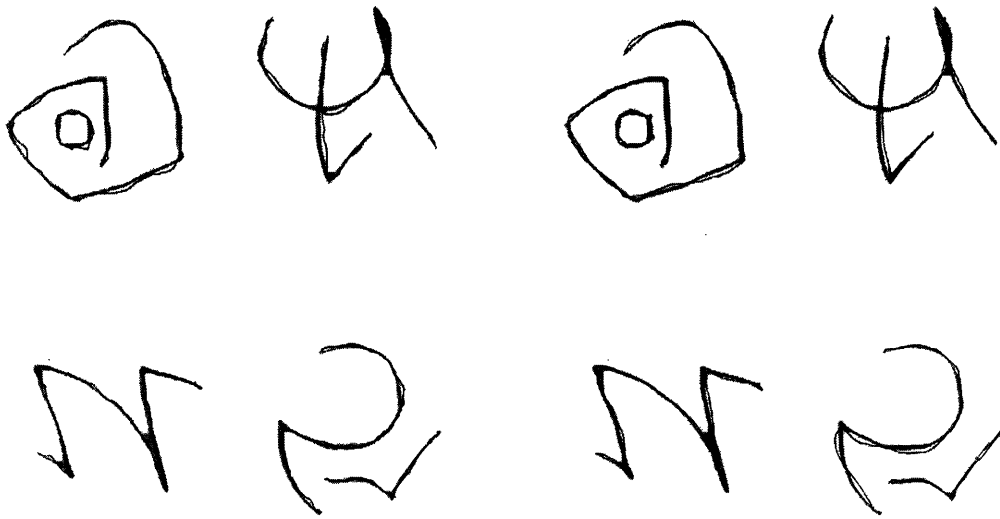
**Additional Observations:**

Lines, whether curved or straight, can be steady or unsteady. The steadier a line is, the fewer the excursions, or bumps, between the two points that it connects. While this was not a calculable metric in this study, it certainly was a characteristic that we observed to be different between the pre-training assessment test and post-training assessment test in many participants.

Comparing the before and after training tests in a member of the feedback group (fig. 3) shows that even inaccurate lines are drawn much steadier. This improvement was also observable in participants from the non-feedback group (fig. 4). Despite a not very significant result in line deviations for this group, there is clearly an increase in the steadiness of the tracing lines. While there is a noticeable steadying of lines in the feedback and non-feedback groups, the controls showed no such progress in their left-handed tracing (fig. 5).

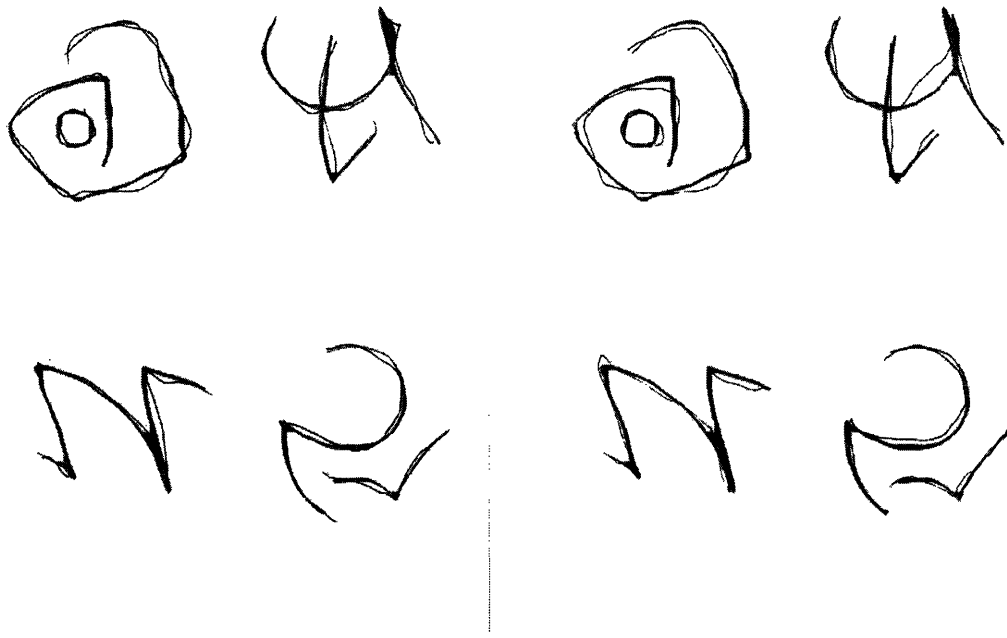


**Figure 3: Left panel: Sample page from the Feedback pre-training assessment test. Right panel: Sample page from the Feedback post-training assessment test.**



**Figure 2: Left panel: Sample page from the Non-Feedback pre-training assessment test. Right panel: Sample page from the Non-Feedback post-training assessment test.**





**Figure 5: Left panel: Sample page from the Control pre-training assessment test. Right panel: Sample page from the Control post-training assessment test.**

**Discussion:**

This study sought to examine two aspects of visuo-motor learning. The first was whether or not an effective training regimen could be created to successfully improve fine visuo-motor skills. The second question concerned the importance of visual feedback in the improvement of the eye-hand coordination learning. The results of this study show that the answers to both of these questions are likely to be in the affirmative.

**Effectiveness of Training:**

The statistically highly significant results from Group 1 suggest that the training regimen outlined by this study can successfully lead to improved eye-hand tracing ability in the non-dominant hand. Also the development in the non-feedback group, while not significant at the .01 level, is certainly noticeable. Also, showing that improvement is not random, or simply achieved

by taking the pre-assessment test, the control group showed no significant decrease in their overall deviations from tracing boundaries between the two tests.

These results suggest that the prescribed training schedule and technique tested in this study is likely an effective one. The continual act of moving the hand through various patterns, and observing the congruence of the resulting trajectory with the reference pattern can improve proficiency on a fine eye-hand coordination task.

### **Importance of Feedback:**

The results of this study strongly suggest that feedback is an important factor in visuo-motor learning. Post-training assessment scores for the group with feedback showed far greater improvement than either of the other groups. The p value of 0.00049 suggests that it is highly unlikely that this improvement was random.

Feedback's role in visuo-motor coordination development is further confirmed by this study's results. While it has previously been shown that altered feedback can distort eye-hand development and learning, our study suggests that feedback is important in exacting significant change or improvement on the coordination of the eye and hand.

### **Improvement of Non-Feedback Group:**

Although not found to be very statistically significant, there is a certainly a trend towards improvement in tracing ability between the pre-training assessment and post-training assessment test results. This suggests that, while feedback is important for improvement, there are other factors involved in this learning process. Simply stated, this suggests that training without feedback may be more effective than doing nothing.

Despite the limited effectiveness of non-feedback training for improving fine visuo-motor coordination, this training did lead to another type of improvement. While not accounted for quantitatively, the steadiness of lines certainly showed signs of improvement between the first and final assessment tests.

### **Line Steadiness:**

In both the feedback and non-feedback groups there was a noticeable steadying of the drawn lines. A majority of the participants drew shaky lines when tracing the given images. These excursions from the intended line accounted for many of the mistakes in all of the pre-training assessment tests.

While the post-training tests did not show a complete disappearance of this jitter, the deviations from the intended line were far less frequent and much subtler for the feedback and non-feedback results. As expected, the control groups showed little to no change in the steadiness of their lines.

Although it can be said that the steadiness of a line is a product of eye-hand coordinated movement, it is likely more dependent on motor control alone. This would account for the improvement in the two groups that received training during this study. These two groups, feedback and non-feedback, were using their left hands to perform fine-motor skills everyday for a week. Regardless of feedback, they were attempting similar hand movements. This likely caused a slight development in their left hand motor manipulation.

Assessing the increased steadiness this way accounts for why both groups had noticeable improvement, while the control group's steadiness remained the consistent over the course of the study. This would also account for some of the improvement seen in the non-feedback group's post-test results.

## **Conclusion:**

This experiment showed that an effective training regimen can be implemented to improve the visuo-motor coordination of the left hand in right-handed individuals. Given the appropriate conditions, there is a significant improvement in the fine eye-hand coordination task of tracing. Feedback was found to be an essential piece for the successful execution of a training program. Despite a noticeable improvement in the non-feedback group, the only group to truly see impressive and significant improvement was the feedback group.

These results support the current notions concerning the importance of feedback. While it has been noted as an integral piece of eye-hand development (White, et al. 1967), and as a necessary dimension to learning tracking and pointing paradigms (Roerdink, et al. 2005), this study additionally suggests that feedback plays a critical role in visuo-motor improvement.

Although not calculated, it is likely that a significant proportion of the observable improvement in the non-feedback group is due to the steadying of their lines. While eye-hand skills development could be the cause for the majority of their progress between the pre-training and post-training assessment, it is more likely to be from their improvement in left-hand motor control. For future studies, it would be helpful to calculate the beneficial effect of straighter lines on decreasing the number of deviant marks. This could allow for a more accurate measurement of the improvement gained through improvement in eye-hand coordination versus the improvement in motor control per se.

Moving forward it would be worthwhile to understand how much feedback is necessary, and whether more information or less information would affect the level of improvement between pre- and post-training tests. Tracing images on a tablet pc could allow for the setting of various levels of feedback, from making sounds every time a participant leaves the boundaries of the tracing image to fading the tracing line to barely visible levels.

This study could also be performed in groups who have impaired visuo-motor skills. The results would help to highlight not only their potential for improvement, but also whether feedback is as able to be as effective in restoring any eye-hand coordination. Developing this task would not only garner information regarding the rehabilitation of specific clinical populations, but also provide a possible training regimen to help improve a stroke victim's or late-sight-onset individual's ability to gain or re-gain visuo-motor coordination.

In summary, we have shown that there exist effective training regimens to improve visuo-motor coordination of fine-motor skills. Essential to this training regimen is the use of feedback. This study shows that training, with feedback, yields impressive and significant improvement in non-dominant hand tracing ability. This helps to not only illuminate the necessity of feedback in visuo-motor learning, but also provides guidelines for how to best create effective techniques for at least some forms of visuo-motor rehabilitation.

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