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Article:

The effect of sensory stimulation combined with mirror box therapy on fine dexterity of the hand: Mobilisation and Tactile Stimulation (MTS)

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Abstract

Purpose: To look at the effect of Mobilisation and Tactile stimulation (MTS) combined with mirror box therapy on fine dexterity of the hand. There is a gap in the literature for the use of mirror therapy, the 9 Hole Peg Test (9HPT) and MTS combined with healthy participants to assess the effects on dexterity in the upper limb.

Method: A before and after study allowed most transparency in answering the research question. Comparison of intervention data against control data was undertaken to allow the effect of sensory stimulation to be identified on motor control. 15 subjects with normal hand function were tested in the MTS group. The 9HPT was performed and timed in seconds, on each hand. MTS was given for 15 minutes on the non-dominant hand, this hand was then put in the mirror box whilst the dominant hand

undertook 10 repetitions of the 9HPT. Finally the 9HPT was performed again on both hands and timed in seconds.
Results: Independent T-test results for non-dominant (p=0.37) and dominant hands (p=0.579) were insignificant and ANOVA result (p=0.845) was also insignificant. The cut off for statistical significance in this study was $p \leq 0.05$.

Conclusion: The results showed no statistically significant effect of sensory stimulation and mirror feedback on affecting motor control, in a healthy, asymptomatic population. The results can be applied to the clinical setting, as it can be speculated, when also looking at other studies, that mirror therapy combined with MTS will have some impact on dexterity of the hand. Further research, using a larger sample size and more rigorous MTS therapy protocol is however needed to justify the findings.

Introduction
Understanding motor control is crucial for a Physiotherapist as a significant amount of rehabilitation is involved with the assessment and treatment of motor control problems. As described in Shumway-Cook and Woollacott (2017, p.3), motor control is 'the ability to regulate or direct the mechanisms essential to movement' and identifies many related theories surrounding this definition with one recurring theme; feedback loops are necessary for skilled movement to be achieved. Sensory input, especially proprioception and perception, are fundamental to the control of functional movement as they provide feedback information about the position of the body in relation to its environment.

The research project undertaken involved the use of mirror therapy, Nine-Hole Peg Test (9HPT) performance and three different sensory variables, which were individually assessed to determine their effect on dexterity. This project focused on the use of Mobilisation and Tactile Stimulation (MTS) as the sensory input and was provided through 15 minutes of the complex manual therapeutic intervention protocol, established by Winter et al. (2013).

In order to test the effect of MTS on motor control, the 9HPT was used. This is the gold standard for measuring manual dexterity, especially in patients with diseases such as Multiple Sclerosis (Rudick et al., 1997).

There seems to be a gap in the literature for the use of mirror therapy, the 9HPT and MTS combined with healthy participants to assess the effects on dexterity in the upper limb; which needs to be addressed. This study intends to fill this gap in the literature.

Method

<u>Study design</u>

A before and after study was chosen as this allowed most transparency in answering the research question. Comparison of the intervention data against control data allowed the effect of sensory stimulation to be identified on motor control.

<u>Recruitment</u>
Ethical approval was gained by the Student Project Ethics Committee (SPEC). Participant recruitment was done by recruitment email sent by the project supervisor to all students within the School of Allied Health Professionals (SAHP) at Keele

University (KU) and recruitment posters situated on public notice boards around the KU Campus.

Participants

Participants included in the study were selected to take part following recruitment - 45 participants took part. The study required healthy participants over the age of 18 who had no specified problems with their upper limbs. Participants were excluded if they had any joint problems, allergies, form of cancer, neurological conditions, trauma, circulation problems or muscular problems in the upper limbs. Mental health and cognitively disordered students were also excluded from the study.

Control Study

Control group data was provided by the project supervisor from a previous undergraduate study of which SPEC approval was granted for the use in future projects. The project title was 'Can a mirror box affect the dexterity of a non-dominant upper limb in a healthy individual?' The control group consisted of 18 participants.

Data Collection

1. Participants were emailed a date, time and location to attend the experiment within the MacKay building at KU.
2. Data collection was conducted in a room with two other researchers present, but not directly involved in the process, due to this being one part of a group project.
3. Upon arrival, a paper copy of the participant information sheet and two consent forms were given to the participant to read through and sign.
4. Participants were given the opportunity to ask any further questions to the researcher.
5. Participants were allocated a number by which they were identified in any further paperwork in order to maintain anonymity.
6. A total of 45 participants responded to the recruitment campaign and were randomly allocated, using a free online randomised computer generator (random.org, 2019), to one of the three sensory intervention groups; MTS, wax or compression. Block randomisation was used to ensure groups were of the same size, in each group n=15.
7. Randomisation was used to reduce the possibility of selection bias. A convenience sample of 45 participants recruited correlated to 19% of the Physiotherapy cohort (three years of students approximately equalled 240). All variables (intervention groups) were performed in the same SAHP practical room over the same data collection session and repeated over 4 data collection days required to meet the target numbers of 15 per intervention group.
8. Each researcher had their own intervention of interest in the study; this project is focussed only on MTS. Each researcher carried out an experiment, (which was not their own) in order to minimise research bias. Researcher and participant blinding was not possible due to the intervention required being varied and visible to all.
9. On entering the room participants were separated by screens and unable to see each other during the tests. They were sat on a chair in front of a plinth, containing the mirror box and 9HPT.
10. The 9HPT was undertaken once initially on the non-dominant hand and once on the dominant hand, both of which were timed using a stopwatch (in seconds).
11. The test was carried out by the participant taking pegs from the container and placing them, one by one, into holes in the board, shown in Figure 1.

12. The participant then had to take out each peg, one by one, and put them back into the container.
13. MTS was then applied to the non-dominant hand and forearm for 15 minutes.
14. The non-dominant hand was then placed into the mirror box before repeating the 9HPT 10 times with the dominant hand. The participant was instructed to look at the mirror box whilst completing the 10 repetitions, shown in Figure 2. These repetitions were not timed; their purpose was to add visual stimulation as stated in the research question.
15. The suggested method for MTS is over a six week period and one hour of treatment daily (Winter et al., 2013). However in this project, due to time limitations and in order to provide the same amount of sensory stimulation to each participant, 15 minutes of treatment was given to each participant, prior to re-assessment of the 9HPT. The treatment protocol followed was Hunter et al. (2006) eight-stage treatment plan.
16. After the 10 9HPT repetitions were completed, the mirror box was removed.
17. The participant was timed completing the 9HPT on the non-dominant and dominant hand.
18. The results were compared to the initial time (seconds) taken to complete the 9HPT on both hands, allowing before and after analysis.
19. The recorded times of each participant were kept on a password-protected laptop in a table correlated to their identification (ID) and not their name.
20. The primary outcome measure was time taken to complete the 9HPT. This proved to be an appropriate outcome measure as time scores were easily acquired with high validity, high inter-rater and test retest reliability (Feys et al., 2017).

Figure 1.
Participant performing 9HPT

Figure 2. Participant performing 9HPT with Non-dominant hand in mirror box

Data Analysis

Statistical hypotheses:

> H_0: "There will be no effect on motor control when using mirror therapy and MTS intervention"
>
> H_1: "There will be an effect on motor control when using mirror therapy and MTS intervention"

The cut off for statistical significance in this study was $p \leq 0.05$.

Results

All participants that responded to recruitment undertook the study. Out of the 15 participants in the MTS group, the ratio of males to females was 6:9 and in the control group, out of 18, the ratio was 10:8. The mean time taken for the control group and experimental (MTS) group for both the Non-Dominant (ND) and Dominant (D) hand can be seen in Table 1 with negative numbers in the difference columns indicating a decrease in time taken to perform the 9HPT.

Table 1. Mean averages of time taken (in seconds) to complete the 9HPT

	Pre ND	Pre D	Post ND	Post D	Diff D	Diff ND
MTS (n=15)	20.21 (±3.58)	18.97 (±2.51)	18.65 (±2.24)	16.71 (±2.10)	-2.26 (±1.99)	-1.4 (±2.68)
Control (n=18)	20.36 (±2.57)	19.09 (±1.72)	19.76 (±2.88)	17.24 (±2.38)	-1.84 (±2.2)	-0.6 (±3.25)

Key: ND = Non-Dominant, D= Dominant, Mean (± standard deviation)

The largest difference in time taken to complete the 9HPT was seen in the D hand in the MTS group, with a -2.26 (±1.99) second decrease and the smallest difference in time was the ND control group, with a -0.6 (±3.25) second decrease, overall all groups got faster at completing the 9HPT.

There was a larger decrease in time for both the ND and D hands in the experimental group versus the control (-1.4 versus -0.6 and -2.26 versus -1.84 respectively) but when an independent t-test was conducted neither difference was statistically significant, p=0.370 for ND and p=0.579 for D, as presented in Table 2. Again, negative numbers indicate a decrease in time taken to perform the 9HPT.

Table 2. T-test equality of mean difference in each hand between groups

	Mean difference between MTS and control groups	95% Confidence interval (CI)		Significance
		L	U	
Non-dominant hand	-0.80	-2.67	1.02	0.370
Dominant hand	-0.42	-1.93	1.10	0.579

Key: L = Lower limit of 95% CI and U = Upper limit of 95% CI

Tests of normality were performed for all results before analysis was undertaken, via the Shapiro-Wilk test (Laerd Statistics, 2018). The before and after data in the control group for the ND hand was p = 0.01, so significant and p = 0.14 for the D hand, so insignificant. There was an outlier value of 11.06 seconds in the ND control group; this was removed for data analysis. The data for both hands in the experimental group were normally distributed, as assessed by the Shapiro-Wilk test (Laerd Statistics, 2018) (p= 0.73 on the ND and p= 0.50 on the D hand; both insignificant. Looking for normality in specific tests is hard for the untrained eye and tests may be unreliable in this study due to the small sample size, potentially missing a clinically meaningful effect in the wider population (Sim and Wright, 2000). Histograms provide visual representation of distribution of discrete or continuous data.

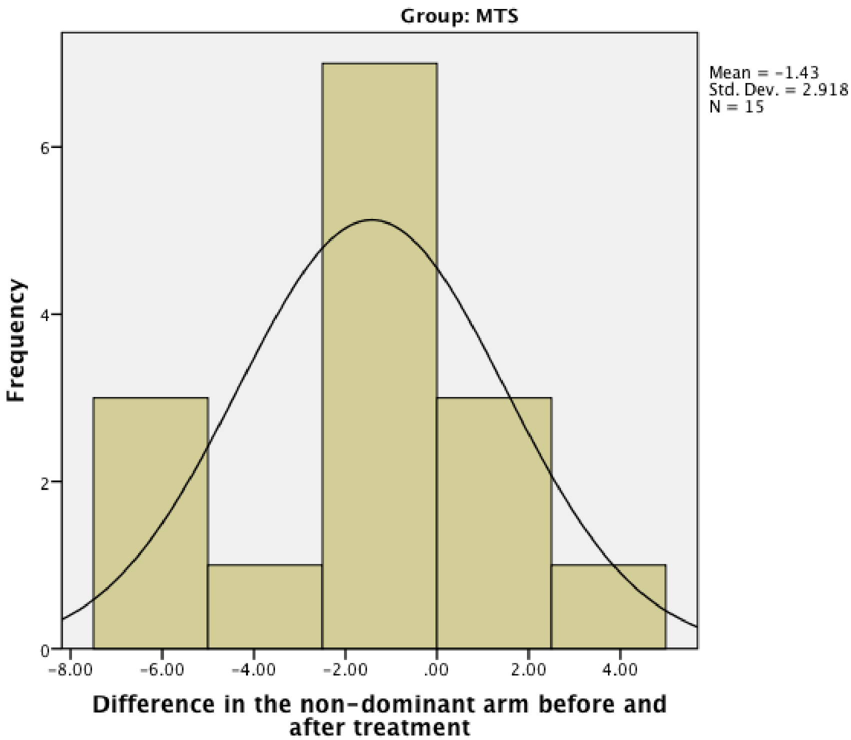

Figure 3. Histogram of normal distribution

Figure 3 shows the ND hand in the MTS group, displaying a symmetrical bell shaped curve - indicating normality.

The statistical hypotheses were tested using the three-way mixed Analysis Of Variance (ANOVA), (Laerd Statistics, 2018). Time taken to complete the 9HPT was normally distributed, as previously assessed by Shapiro-Wilk (Laerd Statistics, 2018) (p>0.05), however, according to Laerds statistics (2018), normality can be assumed when the sample size is small and the ANOVA test can be carried out regardless. Levene's test (Laerd Statistics, 2018), suggested there was equality in variance between groups (p>0.1 in all cases), hence the unadjusted Independent sample t-test results reported.

Mauchly's test, completed through Laerd Statistics (2018), indicated that the assumptions of sphericity were automatically met. There was no statistically significant three-way interaction between, before and after, dominant and non-dominant hands and the intervention versus control. $F(1,31) = 0.039$, $p= 0.845$, partial Eta squared (effect size) = 0.01.

Figure 4 plots the mean differences for each hand in both groups (taken from Table1). This demonstrates a decrease in mean differences between hands and groups, yet with overlapping error bars of no statistical significance. The mean decrease in ND hands across groups is -0.80, compared to that of D hands at -0.42, as outlined in Table 2.

Mean differences in time taken to complete

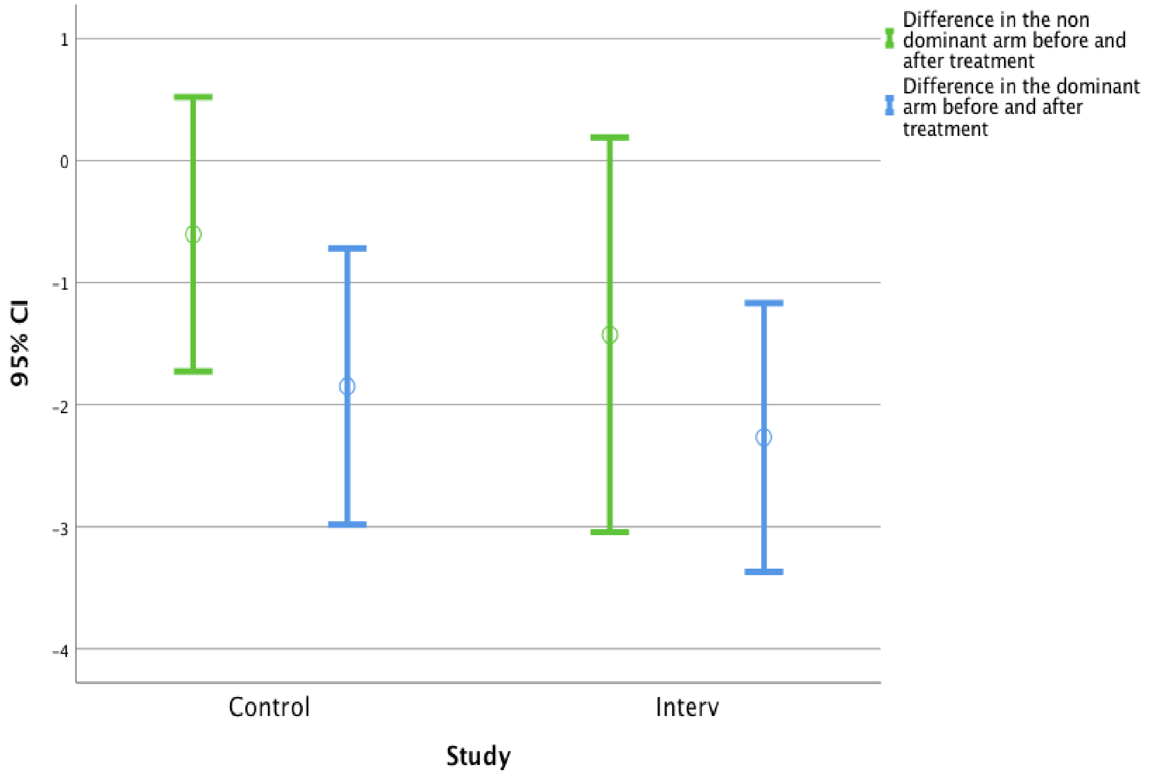

Figure 4. Error plot of mean differences

Figure 5 visually portrays the ANOVA result. The plotted lines, representing hands, all show a downward trend, signifying a decrease in time taken in both hands in both groups, yet insignificant as $p>0.05$. Non-parallel lines show each hand decreased at a different rate. The dominant hands in both groups were faster than non-dominant hands, shown by the lower estimated marginal mean on the Y-axis (approximately 19 compared to approximately 20 seconds pre intervention/control). In the intervention group, both lines are of a steeper gradient than the control group; the steepest line shows the greatest difference (-2.26) being the dominant arm.

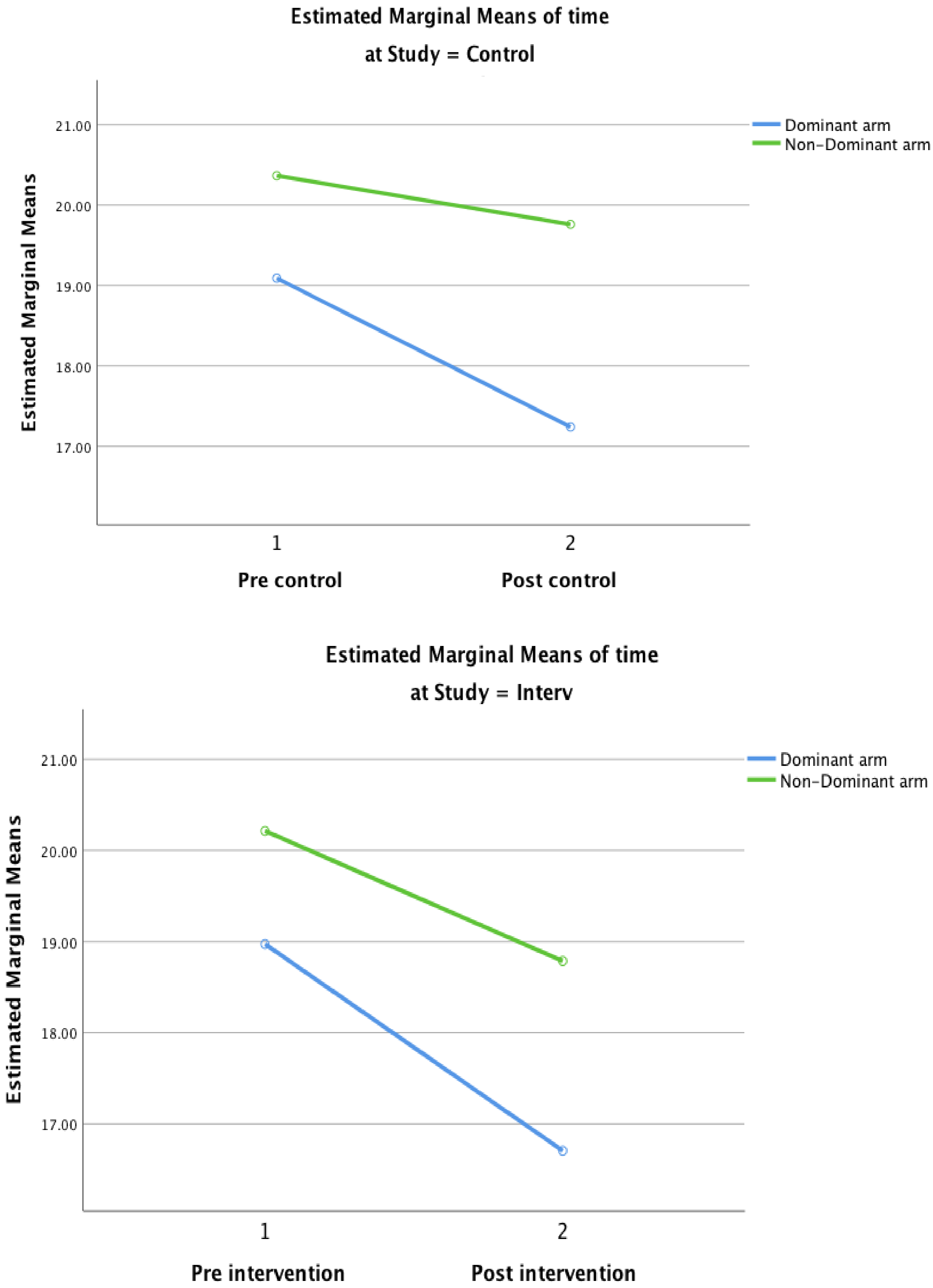

Figure 5. ANOVA line graphs

Discussion

<u>Main findings</u>

The study aim was to establish the effect of sensory stimulation (MTS) combined with mirror therapy on fine motor control (dexterity). The findings confirm the null hypothesis is accepted as there was no significant three-way interaction between the effects of MTS, pre and post intervention, dominant and non-dominant hand on time taken to complete the 9HPT, $p= 0.845$. Furthermore, there was no significant difference between mean differences in each hand between groups, $p = 0.370$ and $p = 0.579$. The impact of MTS combined with mirror box therapy on dexterity of the hand, tested by the 9HPT, therefore did not significantly affect motor control.

MTS as sensory stimulation works by priming the sensorimotor system for movement and has been found to 'improve upper limb motor impairment and functional activity'. The findings are based on one hour a day of MTS intervention for six weeks (Winter et al., 2013, p.693), therefore longer and more consistent MTS sessions would be required in this study undertaken. This would allow for full priming and augmentation of activity in the non-dominant limb, as only 15 minutes were applied, albeit the current results gained from this small study still show slight improvements in motor control with limited MTS.

Mirror therapy has been found to increase muscle activity as well as brain activity in healthy participants (Furukawa, Harue and Jun, 2012). Mirror feedback addresses the interhemispheric imbalance, commonly occurring post stroke, by activating the mirror neuron system. The motor cortex is stimulated when observing arm movement, promoting motor relearning (Zhang et al., 2018). In this study, the participants watched 10 repetitions of the dominant arm undertaking the 9HPT, in the mirror box. This action observation would work to "trick the brain" and recruit mirror neurons, stimulating activity in the non-dominant limb.

The findings suggest that in clinical practice mirror therapy and sensory stimulation can be effective, however this may differ depending on patient group e.g. stroke. Despite insignificance in this study, on average it can be seen that motor control and fine dexterity in both hands increased in both groups, despite high dispersion of standard deviation, ranging between ±1.99 – ±3.25, lowering reliability of mean values (Table 1). This decrease in time taken may be due to the principle of mirror therapy, added MTS or practice repetitions, however many factors aside from those being tested may influence the outcome.

The decrease in time taken for dominant hands, -2.26 seconds, in the study could be attributable to the sensory motor task undertaken whilst looking into the mirror box, providing visual feedback altering the feedback loop. Alternatively the decrease could be due to the 10 practice repetitions undertaken. Repetition can be seen as key to improving dexterity and motor relearning in healthy patients. This has been explored previously, with a study carried out in 2010 showing 'significant increase in upper extremity proprioception and dexterity', ($p=0.013$) following a series of repetitive hand tasks (Rhee et al., 2010, p.689). These results are comparable to results found from this study; with 2.26 and 1.84 second decreases after repetitions had been undertaken on the dominant hand (Table 1) and suggests therefore that practice can correlate to a decrease in time taken to do the 9HPT.

Mean 9HPT time was consistently lower in dominant hands than non- dominant hands before and after, which could be expected (Table 1). Several authors have explored dexterity testing of dominant hands, mainly right-handed dominance. Özcan et al. (2004, p.876) found this hand worked 'significantly faster than non-dominant hands', ($p<0.05$). The better performance of the preferred hand has been attributed to cerebral laterality (Ganong, 1993). Each side of the brain has functional specialisations, differing between individuals, but the contralateral side to the dominant hand may be of higher neural functioning and therefore cerebral dominance, thus, transferrable to this study with the findings of higher dexterity and therefore faster performance seen in dominant hands, with the 9HPT.

The decrease in time taken in non-dominant hands across both groups shown in Table 1 and illustrated in Figure 5, could be attributable to mirror therapy and action observation, possibly enhanced by MTS. The MTS intervention provided somatosensory, proprioceptive and kinaesthetic feedback to the non-dominant limb. This sensory stimulation activates the sensory receptors, due to mechanical deformation, and sends proprioceptive feedback to the brain (Hunter et al., 2006). This could lead to improving sensorimotor function in the non-dominant hand in this study.

The non-dominant hands pre-intervention/control had a mean of around 20 seconds. This is shown by the steepness of the lines in Figure 5. The non-dominant hands also showed a larger mean difference between groups: -0.80 compared to -0.42 on the dominant hand (Table 2). These findings could be due to mirror therapy used in both groups and might suggest MTS helped further improve dexterity of the hand in the intervention group.

Overall, these differences, despite not being significant, support the fact of mirror therapy affecting the mirror neuron system in the brain. The process of watching the opposite hand undertake the 9HPT in the mirror box will send visual feedback, stimulating the motor cortex. With the addition of extra sensory stimulation (e.g. MTS), the sensory motor feedback loop is further influenced, feasibly altering motor control and dexterity of the hands.

Limitations

The first limitation was that a convenience sample size was used, due to the small size of the KU Physiotherapy Cohort and realistic expectations of how many participants would be interested in the study. This meant there were only 15 in the group. However, using a power calculation to determine the optimal sample size for this study would have assured any reliability in significance shown (Lenth, 2001).

The study used data from a previous project for the control. Control data is useful for comparison and enhances analysis (Esser and Vliegenthart 2017), however comes with limitations. The control data used was collected by different researchers, used different participants and during a different year. 18 participants were recruited whereas this study only looked at 15. Amongst others, these variables could affect the results gained, possibly leading to differences shown. Using secondary data can be valuable, however, as stated by Hoffman et al. (2008), validation studies should be completed to examine accuracy of the data collected; this was not the case for this study.

The 9HPT data, time in seconds, was recorded using stopwatches, which are subject to systematic error and random uncertainty (Faux and Godolphin, 2019). Naturally, reaction times differ between individuals. Nevertheless, to try and reduce error, the same researcher performed all data collection for the same group.

Finally, the intervention group only had 15 minutes of MTS due to time restraints. The ideal time would have been 60 minutes, as outlined in the literature (Winter et al., 2013) for full effect on dexterity to be shown. MTS was also not continued whilst the hand was in the mirror box, meaning there was a lag between intervention applied and retesting of the 9HPT, which could have affected results.

Conclusion

The results showed no statistically significant effect of sensory stimulation and mirror feedback on motor control, in a healthy, asymptomatic population. The results could be applied to the clinical setting, as it can be speculated, when looking at other studies, that mirror therapy combined with MTS will have some impact on dexterity of the hand. Further research, using a larger sample size and a more rigorous MTS therapy protocol is however needed to justify the findings.

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