Added meaning and purpose and its effect upon interlimb coupling

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Abstract

This study investigated whether added meaning and purpose influenced interlimb coupling during an occupationally embedded (OE) condition compared to a non-occupationally embedded (non-OE) condition. Interlimb coupling is a phenomenon where when one limb moves, the contralateral limb tends to link to the same movement. It was hypothesized that the occupationally embedded condition would exhibit stronger EMG activity than the EMG activity of the non-occupationally embedded condition. Thirty-three healthy individuals participated in this study and were randomly assigned to an order of presentation group using a counterbalanced design. Participants were asked to turn a knob controlling the height of a bar on a computer screen with their right index finger and thumb in both conditions. In the OE condition, subjects were told that the goal of the task was to match 'their' bar with the height of a target bar. In the non-OE condition, subjects turned the knob back and forth, but the moveable bar was not visible. Wilcoxon signed ranks were used on the correlations for the three muscle groups. The *p*-value for the adductor pollicis comparison did not reveal a statistically significant result, with $p = 0.0568$. However, when comparisons were made with the thenar eminence and FDS, the *p*-value revealed a statistically significant result ($p = 0.0210$, $p = 0.0073$, respectively). For all three muscle comparisons, the OE condition had stronger correlations as compared to the non-OE condition. Adding meaning and purpose into occupationally embedded tasks had a greater effect on the rate of interlimb coupling effecting overall motor performance than rote exercise. Implications from this study suggest that completing meaningful and purposeful tasks enhances the rate of interlimb coupling which can ultimately improve motor performance. Future research needs to be completed that focuses on added meaning and purpose and its effects on interlimb coupling using a special population (e.g., stroke or TBI patients) to follow up on the current study.

Introduction

It is human nature to interact with the environment in everyday occupations. Interactions involve motor control, in which the upper and lower extremities work symmetrically or asymmetrically, unilaterally or bilaterally. Many bilateral movements require the limbs to move independently of each other. For example, hammering a nail in the wall requires holding the nail with one limb and using the contralateral limb to complete the task, in this case, using the hammer. There is a focus of literature devoted to studying how motions of one limb influence the contralateral limb, known as interlimb coupling (e.g. Kelso, Southard, & Goodman, 1979; Kudo, Park, Kay, & Turvey, 2006; Swinnen, & Wenderoth, 2004). Interlimb coupling is a phenomenon where if one limb moves, the contralateral limb tends to link to the same movement, as commonly observed in the rubbing tummy/patting head action (Sugden & Utley, 1995). When a child is born, it is natural for the limbs to be coupled. For example, when an infant is frightened, he/she jumps and often moves the limbs in synchrony with each other. As the child grows to about 8 or 9 years old, it then becomes natural to decrease the prevalence of symmetrical movements (Carson, 2005) and decouple the limbs so they are able to move independently of each other. Life experiences also contribute to the decoupling of the limbs.

The limbs can either work in-phase where the limbs move symmetrically and are coupled, in an anti-phase fashion where the limbs work together rhythmically but asymmetrically to each other, or where both limbs are moving asymmetrically to each other in a totally decoupled fashion. Certain conditions or disabilities can cause motor control issues and often, symmetrical and asymmetrical movements in the upper extremity are more challenging for those with central nervous system impairments (Rice & Newell, 2004). Several studies have investigated interlimb coupling performance in individuals who have a neurological impairment (e.g. Cunningham, Stoykov, & Walter, 2002; Volman, Wijnroks, Vermeer, 2002; Cauraugh, & Kim, 2002; Cauraugh, Coombes, Lodha, Naik, & Summers, 2009). Occupational therapy has a role in helping individuals improve motor skills in performing tasks that require movement and motor control. This study intends to address whether added meaning and purpose will facilitate interlimb coupling. In occupational therapy, it is a core belief that adding meaning and purpose helps the system's ability to organize motor control in a productive fashion.

Although there is no single definitive a neurologically-based theory that explains the phenomenon of interlimb coupling, there are a handful of neurological conjectures. For instance, according to Goble (2006), there are two common neuroanatomical contributors to interlimb coupling: the cerebral cortex along with the corpus callosum and descending motor pathways. At the level of the cerebral cortex, during bimanual and sequential movements, both motor cortices are activated, with each part of the motor cortex controlling the contralateral side of the body. The two hemispheres connect and communicate with each other via the corpus callosum (Ratey, 2001). The corpus callosum is the pathway allowing firing neurons to spread from one hemisphere to the other. Thus the rationale behind callosotomies in individuals with epilepsy is to prevent the propagation of uncontrolled neuronal activity to spread from one hemisphere to the other, thus limiting seizures to a single hemisphere (Lundy-Ekman, 2007). The next neuroanatomical contributors are the descending motor pathways. Information is sent to the spinal cord via the descending motor pathways from the motor cortex. At the level of the medulla, 90% of descending motor axons of the cortiospinal tract cross to activate muscles on the contralateral side, but the remaining axons do not cross and project to muscles ipsilaterally

(Lundy-Ekman, 2007), which is thought to be a neuroanatomical contributor to interlimb coupling (Carson, 2005).

Sugden and Utley (1995) investigated interlimb coupling in 17 children diagnosed with hemiplegic cerebral palsy and compared unilateral to bilateral hand movements while the participants completed a reaching and grasping task. The first experiment required the children to reach and touch spheres in front of them, the second required the children to reach and grasp cubes, and the third required the children to reach and touch a box to the side, then reach and grasp a cube placed in front of them. The three conditions included reaching with the hemiplegic hand, the non-hemiplegic hand, and reaching with both hands. Performance was compared through video observation of limb posture, trajectory and timing of movement, and hand shaping. Evidence of coupling was evident in all three experiments. Of particular interest, during the bilateral condition the non-impaired limb would slow down its movements (compared to when moving unilaterally) to wait for the other hand.

Where Sugden and Utley investigated children with cerebral palsy, others have investigated populations of adults with hemiplegia due to stroke (e.g., Harris-Love, Waller, & Whitall 2005; Rice & Newell, 2001; Rice & Newell, 2004). Rice and Newell (2001) investigated interlimb coupling in 18 left hemiplegic individuals who suffered a cerebrovascular accident and 20 healthy adults. Participants oscillated each elbow both unilaterally and bilaterally at a preferred rate. Each limb’s performance was compared to itself in both conditions. Results showed that in persons with CVA, the unaffected limb was more able to adjust from the unilateral condition to the bilateral condition as compared to the affected limb. That is, unlike the unaffected limb, the affected limb did not differ in movement performance across the two conditions. No differences between the limbs were found in the healthy participants.

In a similar study, Rice and Newell (2004) examined upper extremity interlimb coupling in individuals with left hemiplegia due to stroke. This study compared interlimb coupling of 18 individuals with left hemiparesis with an age-matched control group of 18 unimpaired individuals. Participants engaged in flexion and extension to produce an oscillating movement of the elbows. The limbs moved in asymmetric patterns with one limb oscillating at twice the speed of the contralateral limb. Results showed that individuals with left hemiplegia due to stroke had difficulty with asymmetric movement patterns; they tended to couple their limbs in an in-phase movement pattern more so than the participants in the control group.

Harris-Love, Waller, and Whitall (2005) investigated 32 subjects with chronic stroke and compared unilateral to bilateral movement conditions in motor improvements in paretic arm reaching. The subjects flexed the shoulder and extended the elbow to reach and touch the sides of a box unilaterally with the paretic arm, unilaterally with their non-paretic arm, and bilaterally. The trunk was stabilized to prevent compensation movement of the limbs. Loads were added to non-paretic arm to examine if this would lead to further improvement in the paretic arm. When comparing unilateral versus bilateral reaching, results indicated that using bimanual tasks increased improvement in the paretic arm but loading the non-paretic arm did not improve its function.

Although the previous article suggests that moving bilaterally increases motor improvement, there is also use in exercising the non-impaired limb alone to improve the impaired limb. This can be demonstrated by mirror movements. Mirror movements are a manifestation of the coupling of limbs. Mirror movements are defined as the involuntary movements of muscles in the contralateral limb while the opposite limb is performing unilaterally (Ridderikhoff, Daffertshofer, Peper & Beek, 2005). Mirror movements, detected through electromyography activity, can provide evidence that limbs are coupled.

Chaco and Blank (1974) investigated 25 individuals with hemiparesis without observable mirror movements while 25 healthy subjects were observed as a control group. They measured mirror movements, through EMG activity, of the affected hand during voluntary movements of the unaffected hand. No action potentials were found within the 25 healthy subjects. However, they found an action potential in 10 of the 15 participants with hemiparesis during both of the movements tested: opposition of the thumb and abduction the fifth finger of the unaffected limb. The EMG recorded that the muscles in the affected limb were contracting but not enough motor units were firing to cause limb movement.

Cernacek (1961) investigated motor irridation, or mirror movements, in 21 healthy subjects through EMG activity during flexion, extension and forced flexion of the index finger. This researcher found that contralateral motor irradiation occurred in every subject, and the dominate side irridations were significantly greater than the subordinate side but in ambidexters, irradiations were the same from both sides. The results were compared to 18 subjects with hemiparesis, in which 11 subjects had hemiparesis on the subordinate side, 5 subjects had hemiparesis on the dominant side, and 2 subjects were ambidexters. There was no significant difference when comparing motor irradiation from the dominant limbs in healthy subjects and subjects with hemiparesis. The number of motor irradiations was significantly higher in the contralateral subordinate limb (regardless if the limb was affected by the condition) in those with hemiparesis compared to the healthy subjects (Cernacek, 1961). Although the study is dated, its findings are particularly pertinent for occupational therapy practitioners who work with individuals with hemiplegia.

Meaning and Purpose

In occupational therapy, adding meaning and purpose to an individual's occupational form enhances learning and occupational performance. Meaning is defined as the physical, sociocultural, and affective experiences that on engages in during an occupational form (context and environment surrounding the occupation). Once one interprets meaning in a situation, they often wish for an outcome. The felt experience of wishing for an outcome is known as purpose (Nelson & Jepson-Thomas, 2003). Gliner (1985) believes that occupations that have purpose can enhance motor skill learning. Licht and Nelson (1990) found that added meaning to an occupation significantly enhances performance. Meaning and purpose can be enhanced in occupational therapy by incorporating occupationally embedded exercises over rote exercises.

A study by Ferguson and Trombly (1997) compared rote versus added purpose and meaningful exercises and their effects on motor learning. The study consisted of 20 university students who were randomly assigned to one of two conditions: added-purpose or rote exercise. The task consisted of completing three five-note patterns on an electric keyboard that was camouflaged in both conditions. In the added-purpose condition, the three five-note patterns produced a musical sound whereas in the rote conditions, the exercise did not produce a sound. The results indicated the added purpose enhanced motor skill retention, but the level of meaningfulness had no effect on motor learning.

Sietsema, Nelson, Mulder, Mervau-Scheidel, and White (1993) studied rote versus occupationally embedded tasks to improve arm reach in 20 individuals with traumatic brain injury. The occupationally embedded task used to promote arm reach was a computer-controlled game, Simon™. The quality of movements from the computer-controlled game was compared to the quality of movements from rote exercises. Individuals in the occupationally embedded group tended to reach an average of 12 cm farther than the participants in the rote exercise group. Additionally, Sietsema et al. found that participants in the occupationally embedded condition displayed a wider range of motion as well as more enthusiasm and a longer attention span than those participants in the rote exercise group.

Facilitating the perception of meaning and purpose to occupations can enhance motor learning and occupational performance. It has been shown that if there is purpose for completing a task, the probability for success in cross transfer from one limb to the contralateral limb is enhanced. Interlimb coupling is associated to cross-transfer in the sense that movement of one limb will benefit the contralateral limb; cross-transfer effects cannot take place without the underlying phenomenon of interlimb coupling. Rice (1998) described cross transfer as when a limb is trained unilaterally for a given amount of time, performance will increase not only in the trained limb, but in the untrained limb as well. Nagel and Rice (2001) investigated cross-transfer effects during an occupationally embedded task that involved a fine motor skill: completing a plastic toy maze with a metal ball. Forty-eight participants were randomly assigned to either a training group or a control group. Both groups completed a pre-test, the training group trained three times a day for seven days, and then both groups completed a post-test. Post-test results showed that there was a significant decrease in movement time and force oscillations for the untrained limb of those in the training group. These results suggest that cross-transfer can occur in an adult population during an occupationally embedded task.

Rice (1998) investigated the purposefulness and cross transfer in a forearm supination and pronation task as well as improvement in movement time between the trained and untrained limb. This study entailed three groups: a rote exercise group, a materials-based group, and a control group. After taking a pre-test, participants in the materials-based group as well as the rote exercise group trained for six days (with the limb that was untested at the pre-test). A post-test was then given. Participants in the materials based group were given a practice device whereas the participants in the rote exercise group were assigned to either pronate or supinate their assigned limb for a certain amount of time. The materials-based group displayed more improvement in movement time than the control and rote exercise groups. It was also found that participants in the materials-based group had better movement time while the untrained limb preformed the opposite movement than what the trained limb preformed. This suggests that a cross transfer effect occurred but it was not necessarily because of a specific muscle group, but rather the perceived meaning of task (i.e., the goal of the task) that lead to the effect (Rice, 1998). Eastridge and Rice (2004) conducted follow-up study that investigated the effect that a task goal had on a cross-transfer effect during a supination and pronation task. The findings of this study were similar to, and therefore supported the findings from the study by Rice (1998). Specifically, Eastridge and Rice found that cross-transfer effects occurred, but the improvements were not bound to the contralateral muscle group but rather had the strongest effect with the contralateral muscle group that shared the same goal.

The previous studies provide evidence that associating meaning and purposefulness contribute to the success of the transfer of skill from one limb to the contralateral, untrained limb. This supports one of the central tenets of occupational therapy: that adding meaning and purpose to a task can increase occupational performance. There is also literature investigating the effectiveness of added meaning and purposefulness with mirror movements during interlimb coupling. As mentioned above, interlimb coupling is associated with cross-transfer in the sense that training with one limb benefits the contralateral limb, particularly if meaning is associated with the training task. With cross-transfer, there is a period of training whereas interlimb coupling can occur at anytime movement occurs within any limb, including the initiation of movement. This presents the question that if added meaning and purpose effects cross-transfer effects through training, will it have the same effects at initial movement? The purpose of this study is to investigate whether added meaning and purpose will influence interlimb coupling by interpreting surface electromyographic readings of the upper limb during mirror movements. Therefore, it is hypothesized that the occupationally embedded condition will exhibit stronger EMG activity than the EMG activity of the non-occupationally embedded condition.

Methods

Subjects

A sample of 33 participants were recruited via flyers and through word-of-mouth. Included in this sample were 7 males and 26 females. The mean age was 30.63 (*SD* = 10.63). Inclusion criteria included participants between the ages of 18-65 and who self-reported having no neurological or orthopedic condition that would adversely affect their performance with the study. Out of the 33 recruited participants, 31 were right hand dominated and two were left hand dominated.

Apparatus

Muscle activity was measured using a Noraxon, TeleMyo 2400T EMG device. A Dell Optiplex 755 desktop PC was used to operate the Noraxon program. The EMG device, Noraxon Signal Processing Module of Myo Research v.2.11.15, measured the muscle activity (see Figure 1) during the following movements of the thumb: flexion, extension, abduction, and opposition. Electrodes from the Noraxon device were placed on the thenar eminence (opponens pollicis, abductor pollicis brevis and the flexor pollicis brevis), adductor pollicis, and the flexor digitorum superficialis (FDS) of both extremities (see Figure 2). A second computer, a Gateway Solo laptop, that housed a custom designed computer software application using Testpoint version 3.4 (Capital Equipment Corporation, 900 Middlesex Turnpike Building 2, Billerica, Massachusetts 01821) administered the various conditions of the independent variable.

Procedure

Informed consent was obtained prior to any data collection. Data were collected at The University of Toledo, Toledo, Ohio. Demographic data including age, gender, and hand dominance were gathered initially. Hand dominance was measured using Edinburgh's Handedness Inventory (Williams, 1986). Electromyography sensors were placed on the surface of the muscle bellies of the thenar eminence (opponens pollicis, abductor pollicis brevis and the flexor pollicis brevis), adductor pollicis, and flexor digitorum superficialis both arms.

Once testing was started, all subjects were randomly assigned to an order of presentation group (e.g., OE/Non-OE; Non-OE/OE) using a counterbalanced design. In both conditions, the participants were asked to turn a knob connected to a potentiometer (see Figure 3) with their right index finger and thumb. In the occupationally embedded condition, the potentiometer was interfaced with a bar on a computer screen that controlled the height of a moveable bar in order to match levels with a 'target' bar on the same screen (see Figure 4). Specifically, subjects were told that the goal of the task was to match 'their' bar with the height of the target bar as closely as possible and was instructed that turning the knob clockwise would increase the size of the bar while turning the knob counterclockwise would decrease the size of the bar. During the non-occupationally embedded condition, subjects were asked to turn the knob back and forth, but the moveable bar was not visible. In both conditions, there was an audible sound indicating the initiation and the cessation of the trial. In both conditions, there were 15 trials; each trial was 5 seconds in length and there was a 5 second break between trials.

Statistical Analysis

Noraxon Signal Processing Module of Myo Research was used to process the EMG data. Specifically, raw EMG data were full-rectified, filtered using a 15-350 Hz notch filter, and were smoothed using a root-mean-squared algorithm with a 50 ms window. The signal was then normalized using the maximum amplitude across each individual trial. The data were originally concatenated and depending on the order of presentation the first portion of the data were either associated with the OE condition or the Non-OE condition while the second portion was associated with the opposite condition. The data for each condition were separated into individual files. The EMG data from the left upper extremity were correlated with the homologous EMG data from the right upper extremity. This was done for each condition. Those correlations that were statistically significant were included in the data analysis (see Tables 1- 3). These data were skewed and therefore a Wilcoxon signed rank test was used to analyze the difference between the two conditions.

Results

Data from three participants were discarded due to equipment failure (electrodes falling off and computer malfunction). Therefore data from 30 participants were analyzed. Homologous comparisons were examined for each muscle tested for both conditions. Results are presented in Table 4. The p-value for the adductor pollicis comparison did not reveal a statistically significant result, with $p = 0.0568$ and the effect size (d) at 0.048. However, when comparisons were made with the thenar eminence, the p-value revealed a statistically significant result ($p = 0.0210$), with the effect size (d) at 0.302. In addition, when the FDS was compared, the p-value, again, was found to be statistically significant at 0.0073 and $d = 0.417$.

For all three muscle comparisons, the OE condition had stronger correlations as compared to the non-OE condition, supporting the hypothesis. The correlation value (*r*) of the adductor pollicis in the OE condition was 0.027 and the *r* in the Non-OE condition was found to be -0.006, revealing that the homologous muscles in the OE condition were more correlated than the muscles in the Non-OE condition (see Figure 5). When examining the correlations for the homologous muscles of the thenar eminence, a greater correlation was revealed in the OE condition ($r = 0.086$) as compared to the Non-OE condition ($r = 0.045$, see Figure 6). Comparable to the other muscles tested, the FDS muscles were also found to have a stronger correlation ($r = 0.029$) in the OE condition as compared to the non-OE condition ($r = 0.003$, see Figure 7). According to Tomita (2006), when $r= 0.20$, it typically suggests that there is a weak or negligible correlation and there is little relationship. Even though all correlations found were weak, the muscles in the OE conditions were more correlated than the muscles in the Non-OE condition.

Discussion

The purpose of this study was to investigate whether added meaning and purpose would influence the rate of interlimb coupling as interpreted by surface electromyographic readings of the upper limb during mirror movements during an OE condition and a Non-OE condition. Results from this study showed that during the OE condition, there was more interlimb coupling amongst the muscles as compared to the non-OE condition. Results indicated that the correlations between the homologous muscles of the thenar eminence and flexor digitorum superficialis during the OE condition were stronger than the correlations in the non-OE condition. Therefore, the hypothesis that the OE condition will display stronger EMG activity than the EMG activity of the non-occupationally embedded condition is supported.

The findings from this study are largely consistent with those in the past (e.g. Sugden & Utley, 1995; Kelso, Southard, & Goodman, 1979; Kudo, Park, Kay, & Turvey, 2006; Swinnen, & Wenderoth, 2004) in that the motions of one limb influence the contralateral limb. Additionally, this study is similar to the findings of Ferguson and Trombly (1997) in terms of the importance of adding meaning and purpose to therapeutic tasks. Ferguson and Trombly (1997) investigated added meaning and purpose as compared to rote exercise and their effects on motor learning during an upper extremity task. Results indicated that adding purpose to tasks enhances motor skill retention more so then strictly rote exercise. In addition, Licht and Nelson (1990) investigated the effects of adding meaning and purpose to a visuomotor task. Results from this study revealed that adding meaning to an occupation significantly enhances motor performance. Further, Sietsema, Nelson, Mulder, Mervau-Scheidel, and White (1993) studied rote versus occupationally embedded tasks on 20 individuals with traumatic brain injury. The quality of movements from the occupationally- embedded task was compared to the quality of movements from rote exercises. Sietsema et al. found that participants in the occupationally embedded condition displayed a wider range of motion as well as more enthusiasm and a longer attention span than those participants in the rote exercise group. Results from these studies are comparable to the results from the current study in that adding meaning and purpose enhances occupational performance.

To further demonstrate the importance of the results of the current study that adding meaning and purpose enhances motor performance, this study can be compared to studies (e.g. Nagel & Rice, 2001; Rice, 1998; Eastridge & Rice, 2004) that investigated added meaning and purpose and its effect upon cross-transfer. Interlimb coupling is associated with cross-transfer in the sense that training one limb can also benefit the skills or ability in the contralateral limb; the effects of cross-transfer cannot take place without interlimb coupling. Nagel and Rice (2001), examined if cross-transfer effects were evident in an occupationally embedded task with individuals who completed a training period as compared to cross-transfer effects of a control group. Post-test results demonstrated that there was a significant decrease in movement time and force oscillations for the untrained limb of those in the training group while completing the occupationally embedded task as compared to the effects in the control group.

As mentioned earlier, Rice (1998) investigated added purpose and its effects on cross transfer. It was found that individuals completing the task with added purpose displayed improvement in movement time while the untrained limb preformed the opposite movement as compared to a control and rote exercise groups. This suggests that a cross transfer effect occurred but it was not necessarily because of a specific muscle group, but rather the perceived purpose of task that led to the effect (Rice, 1998). In addition, Eastridge and Rice (2004) conducted follow-up study that investigated the effect that a task goal had on a cross-transfer effect. It was found that cross-transfer effects occurred, however, improvements were not bound to the contralateral muscle group but rather had the strongest effect with the contralateral muscle group that shared the same goal. These past studies (i.e. Nagel & Rice, 2001; Rice, 1998; Eastridge & Rice, 2004) provide evidence that associating meaning and purpose to a task contributes to the success of the transfer of skill from one limb to the contralateral limb. The findings from the current study are similar with the studies on added meaning and purpose and cross-transfer in the fact that added meaning and purpose enhances motor performance. This supports one of the central tenets of occupational therapy: that adding meaning and purpose to a task can increase occupational performance.

Although the current study was based on typically-developing and healthy individuals, the results can still be applied to occupational therapy practice. Findings from this study suggest that interlimb coupling is enhanced when there is added meaning and purpose to a task, one of the central concepts of occupational therapy. Practitioners can take the findings from this study and apply the theory and concept into clinical settings. As discussed previously, cross-transfer effects cannot occur without the phenomenon of interlimb coupling. If a practitioner is working with a patient with an impaired limb, the practitioner can exercise the non-impaired limb to ultimately regain function in the impaired limb (i.e. effects of exercising the non-impaired limb will transfer over to the affected limb). In addition, if a practitioner implements meaning and purpose into intervention efforts and exercises the non-affected limb, it is possible that interlimb coupling will occur and possibly lead to a cross-transfer effect to enhance performance of the affected limb.

A limitation to this study is that it had a small sample size and was composed of healthy individuals, so generalization to special populations needs to be done with caution. Additional research on interlimb coupling is needed, particularly with different age groups and to groups with disabilities. Further, future studies could focus on added meaning and purpose and its effects upon interlimb coupling with special populations, such as cerebral vascular accidents, or tramautic brain injuries. These populations typically have one impaired limb and if this line of research provides evidence that added meaning and purpose enhances interlimb coupling, then this phenomenon could be more directly used as a strategy to increase the motor performance of the impaired limb.

Conclusion

This study demonstrates that adding meaning and purpose to a simple motor task enhanced interlimb coupling by virtue of EMG muscle activity in a normal population. Implications from this study suggest that completing meaningful and purposeful tasks enhances the rate of interlimb coupling which can ultimately improve motor performance. As specific to occupational therapy, when working with a patient with an impaired limb, a practitioner can exercise the non-impaired limb to regain function in the impaired limb. In addition, a practitioner should implement meaning and purpose into treatment as well as exercise the non-affected limb because interlimb coupling will possibly occur which, in turn, would lead to a cross-transfer effect that enhances performance of the affected limb. However, generalization to special populations needs to be done conservatively due to this study investigating only healthy individuals. Future research needs to be completed that focuses on added meaning and purpose and its effects on interlimb coupling using a special population (e.g., stroke or TBI patients) to follow up on the current study. Future studies that focus on a special population is important to the field of occupational therapy because if results are prove effective, practitioners can implement evidence into practice.

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Table 1

Adductor Pollicis: N, r, and p-values for each subject.

	OE			Non-OE		
Subject	N	r	*p*	N	r	*p*
1012	392735	-.078	.000	193814	-.105	.000
1021	175382	.148	.000	361892	.029	.000
1032	363493	.077	.000	175701	-.020	.000
1041	177278	.025	.000	358301	-.025	.000
1062	399352	-.054	.000	287712	-.086	.000
1072	362749	.018	.000	174886	.015	.000
1082	362210	.05	.000	175993	.077	.000
1091	188757	-.028	.000	377587	-.051	.000
1101	86768	-.066	.000	355315	.034	.000
1111	173599	-.019	.000	359145	.157	.000
1121	173601	-.008	.001	366733	.021	.000
1132	353234	.017	.000	187715	.009	.000
1142	365895	.249	.000	177784	.004	.096
1162	380048	-.039	.000	176621	-.019	.000
1171	186024	.034	.000	355404	-.016	.000
1181	177864	-.011	.000	364165	.03	.000
1192	358109	-.005	.004	176270	-.01	.000
1202	388770	-.026	.000	187429	-.029	.000
1211	187572	-.024	.000	393149	.017	.000
1221	199210	.128	.000	376763	-.226	.000
1232	390540	-.011	.000	188283	.023	.000
1241	195969	.011	.000	394054	.03	.000
1252	368853	.037	.000	178756	.002	.395
1261	177263	-.004	.137	362936	.005	.002
1282	372837	.135	.000	174186	.093	.000
1292	368081	-.003	.035	175613	.008	.001
1301	177235	.023	.000	363818	-.062	.000
1312	362439	-.023	.000	177960	-.034	.000
1321	187918	.023	.000	391821	-.011	.000
1332	364508	-.012	.000	176650	.027	.000
1511	178549	.125	.000	359939	.064	.000
1521	184248	.002	.385	362011	.013	.000
2011	178868	.069	.000	363386	.097	.000

Table 2

Thenar Eminance: N, r, and p-values for each subject.

	OE			Non-OE		
Subject	N	r	*p*	N	r	*p*
1012	392735	.065	.065	193814	-.010	.000
1021	175382	.018	.018	361892	-.133	.000
1032	363493	.000	.962	175701	.020	.000
1041	177278	.082	.000	358301	-.021	.000
1062	399352	-.027	.000	287712	.028	.000
1072	362749	.058	.000	174886	.002	.321
1082	362210	.082	.000	175993	.091	.000
1091	188757	.024	.000	377587	-.031	.000
1101	86768	.397	.000	355315	.241	.000
1111	173599	.002	.371	359145	.063	.000
1121	173601	.048	.000	366733	.006	.001
1132	353234	.063	.000	187715	.067	.000
1142	365895	.119	.000	177784	.305	.000
1162	380048	-.022	.000	176621	.019	.000
1171	186024	.209	.000	355404	-.002	.211
1181	177864	-.014	.000	364165	.008	.000
1192	358109	-.004	.01	176270	.000	.931
1202	388770	-.024	.000	187429	.008	.000
1211	187572	-.009	.000	393149	-.034	.000
1221	199210	.095	.000	376763	-.01	.000
1232	390540	.095	.000	188283	-.006	.008
1241	195969	.063	.000	394054	-.04	.000
1252	368853	-.011	.000	178756	.124	.000
1261	177263	.249	.000	362936	.073	.000
1282	372837	.005	.003	174186	.008	.000
1292	368081	.105	.000	175613	.001	.823
1301	177235	.104	.000	363818	-.046	.000
1312	362439	-.015	.000	177960	-.007	.004
1321	187918	.042	.000	391821	-.016	.000
1332	364508	.002	.246	176650	-.028	.000
1511	178549	.586	.000	359939	.602	.000
1521	184248	.001	.601	362011	-.001	.483
2011	178868	.154	.000	363386	.123	.000

Table 3

Flexor Digitorum Superficialis: N, r, and p-values for each subject.

	OE			Non-OE		
Subject	N	r	*p*	N	r	*p*
1012	392735	.069	.000	193814	.048	.000
1021	175382	.015	.000	361892	.000	.878
1032	363493	-.07	.000	175701	.038	.000
1041	177278	-.07	.004	358301	-.011	.000
1062	399352	.054	.000	287712	.006	.001
1072	362749	.077	.000	174886	- .015	.000
1082	362210	.063	.000	175993	-.035	.000
1091	188757	.063	.000	377587	.016	.000
1101	86768	.022	.000	355315	.016	.000
1111	173599	.001	.648	359145	.041	.000
1121	173601	.073	.001	366733	.052	.000
1132	353234	.002	.324	187715	.08	.000
1142	365895	.276	.000	177784	.028	.000
1162	380048	.142	.000	176621	.068	.000
1171	186024	-.005	.019	355404	-.014	.000
1181	177864	.026	.000	364165	-.049	.000
1192	358109	.007	.004	176270	.005	.033
1202	388770	.011	.000	187429	.049	.000
1211	187572	.015	.000	393149	.018	.000
1221	199210	-.023	.000	376763	-.206	.000
1232	390540	.072	.000	188283	-.038	.000
1241	195969	-.052	.000	394054	-.066	.000
1252	368853	.057	.000	178756	-.08	.000
1261	177263	-.012	.000	362936	.139	.002
1282	372837	.041	.000	174186	-.002	.503
1292	368081	.02	.000	175613	-.012	.000
1301	177235	-.009	.000	363818	-.039	.000
1312	362439	-.05	.000	177960	-.024	.000
1321	187918	-.047	.000	391821	-.024	.000
1332	364508	.072	.000	176650	-.139	.000
1511	178549	-.028	.000	359939	-.056	.000
1521	184248	.132	.000	362011	.068	.000
2011	178868	.006	.007	363386	-.008	.000

Table 4

Wilcoxon Signed Ranked Test Comparing OE vs. Non-OE.

Muscle	Sum +	Sum -	*W*	*p*	*d*
Adductor Pollicis	291.0	-144.0	147.0	0.0568	0.4796
Thenar Eminance	247.0	-104.0	170.0	0.0210	0.3019
FDS	291.0	-87.0	193.0	0.0073	0.4171

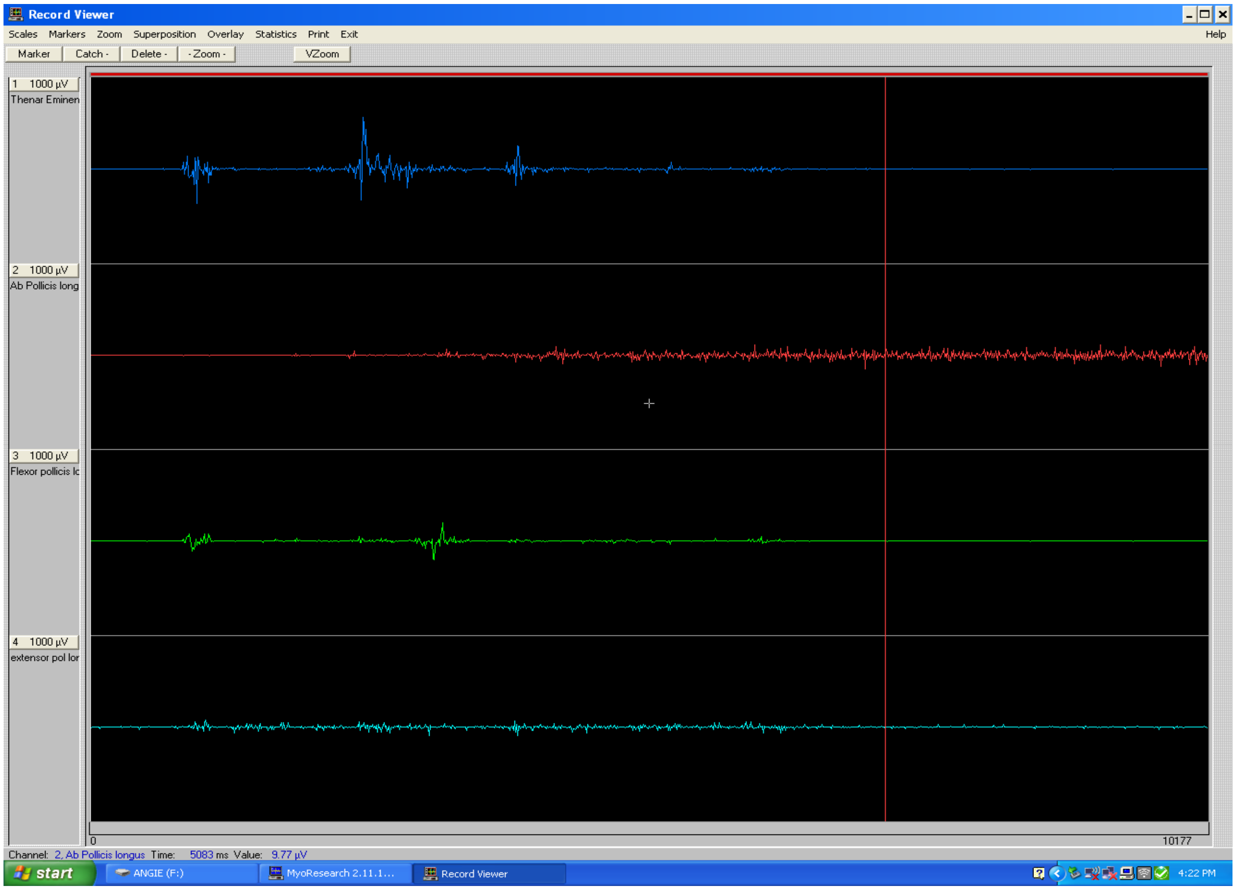

Figure 1. EMG readings of muscle activity.

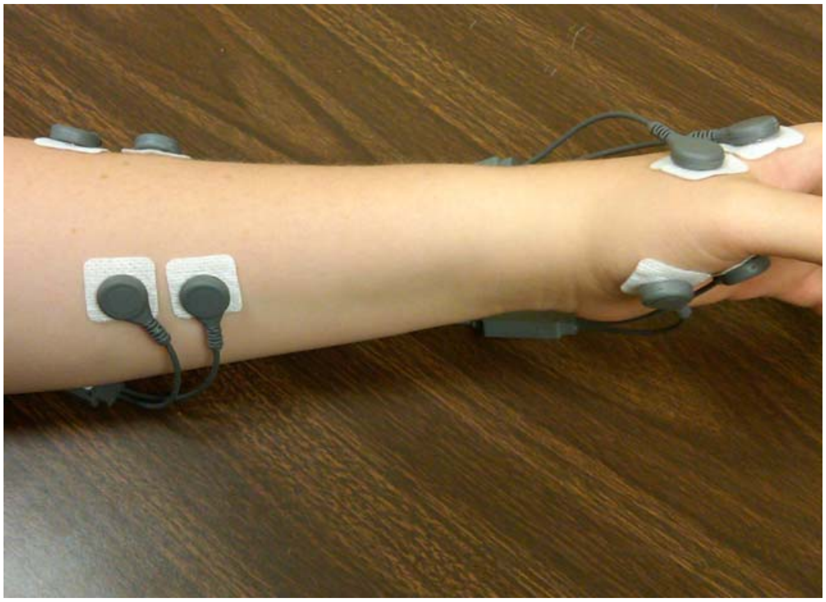

Figure 2. Electromyography sensors on the thenar eminence, adductor pollicis, and the flexor digitorum superficialis (FDS).

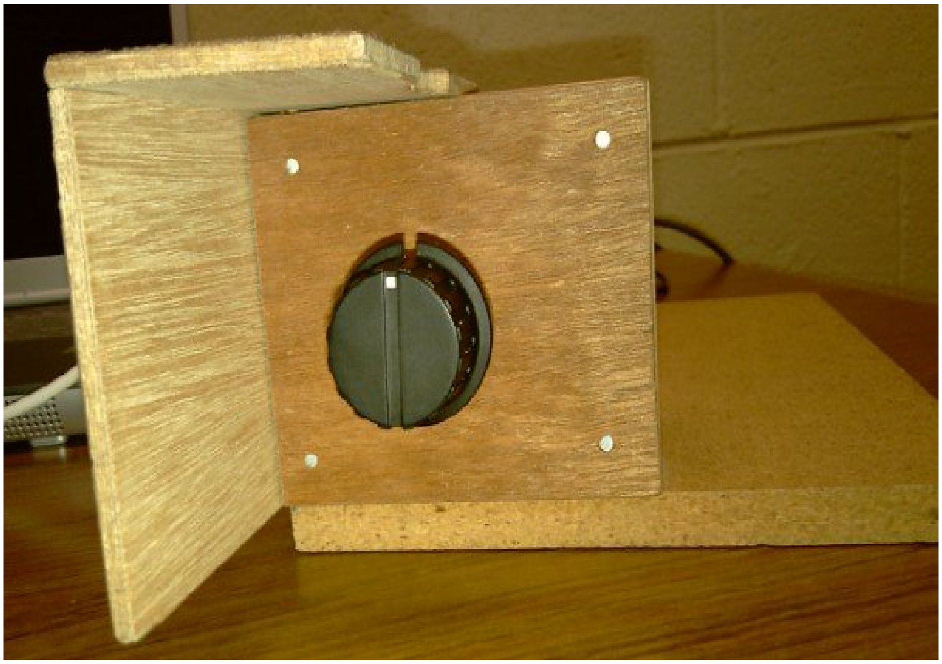

Figure 3. Poteniometer knob.

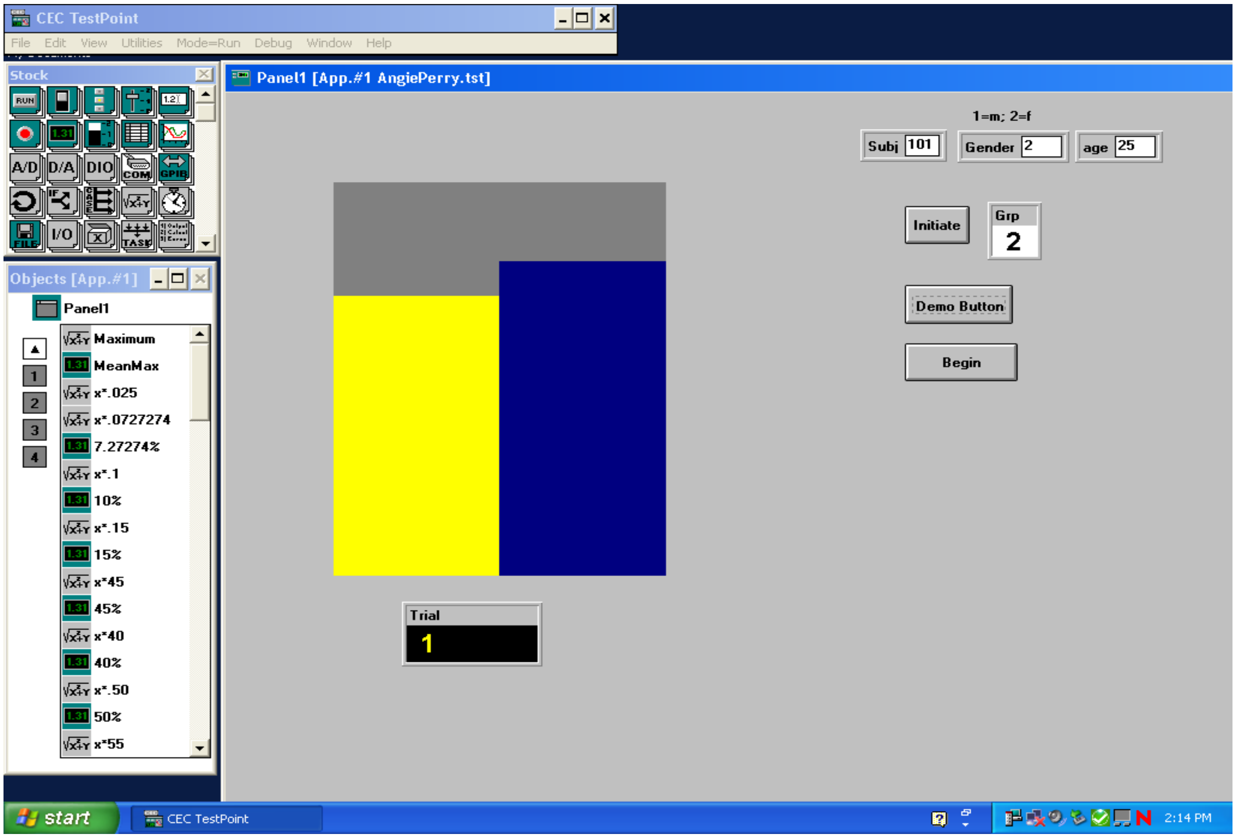

Figure 4. OE condition.

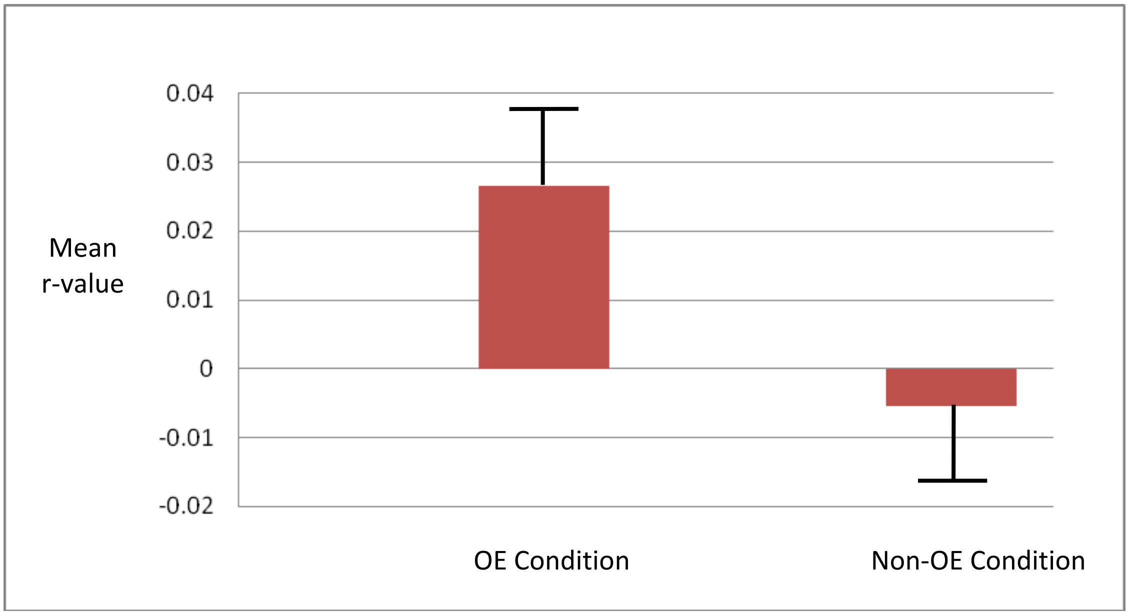

Figure 5. Mean and standard deviation of the correlation of the adductor pollicis muscles during the OE versus the Non-OE Condition.

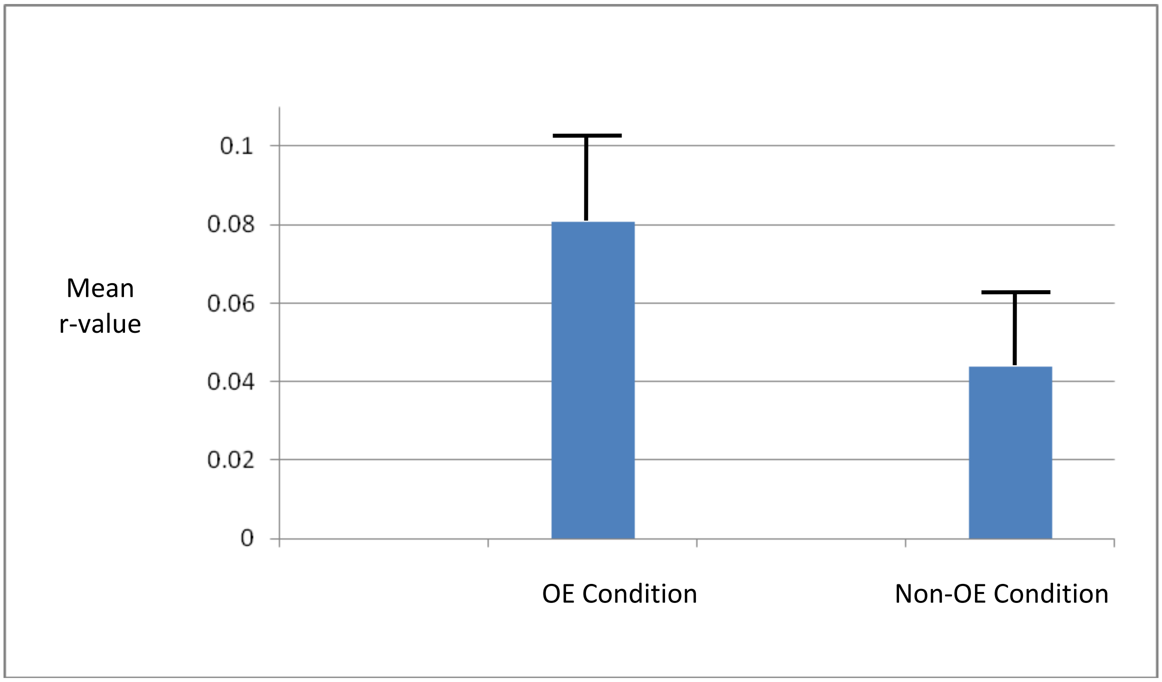

Figure 6. Mean and standard deviation of the correlation of thenar eminence during OE versus the Non-OE condition.

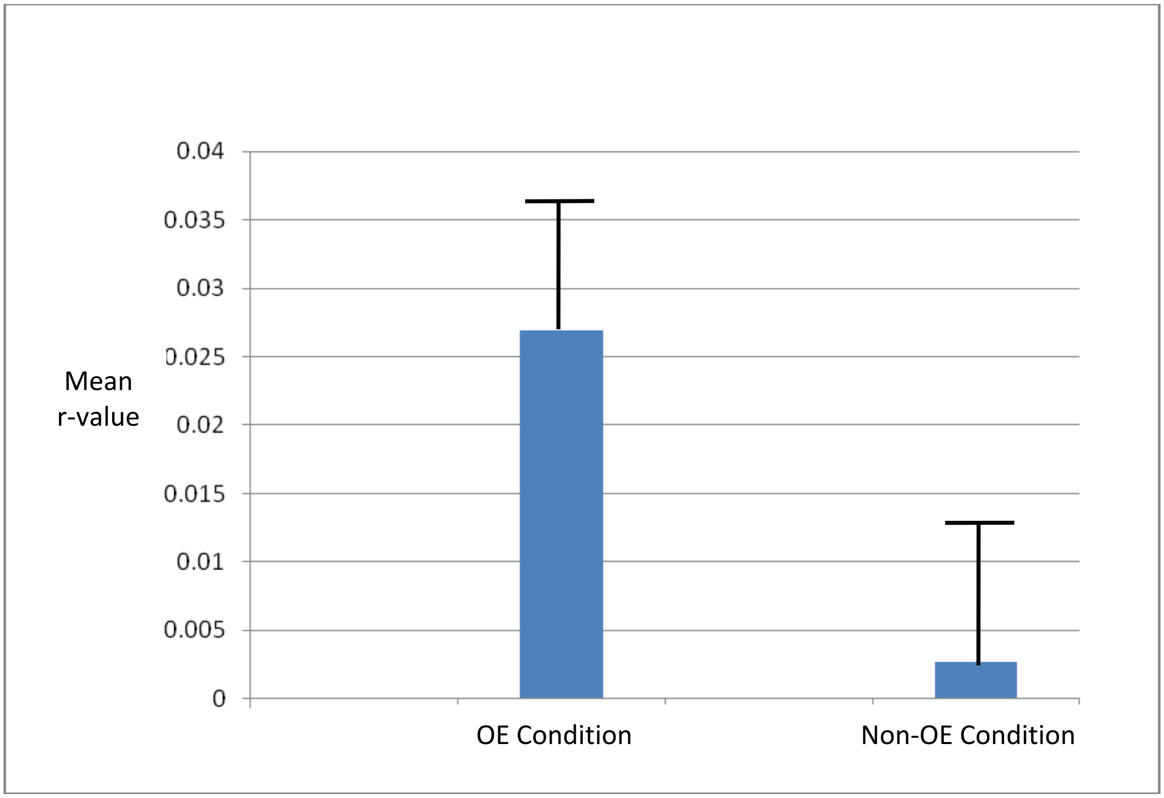

Figure 7. Mean and standard deviation of the correlation of FDS during OE versus the Non-OE condition.