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Effects of Cognitive Load on Inter-Phase Transfer of Bimanual Coordination Patterns in Elderly

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Bimanual coordination is a significant ability that is used in many daily tasks including bottoming cloth, driving, picking, throwing, catching and many sport skills. Performing these activities depends on many factors such as age, gender, and attention limitations. The purpose of this research was to compare the inter-phase transfer of bimanual coordination patterns in aged men and women with/or without cognitive load when hand movements speed were gradually increased. In this experimental research, one group of healthy volunteer men (n=10) and women (n=10) aged between 60 to 74 years participated in a bimanual coordination task. The instrument used to examine the transfer phase was a set made by Pedidar-Omid Farda Co. Analysis of variance was employed to analyze the data. The result indicated that cognitive load had a significant effect on transfer phase of bimanual coordination patterns (P=0.001). However, there was no significant difference between the gender nor there was any interaction effect (P>0.05). The results of present research indicated that cognitive load had an impairing effect on bimanual coordination and causes faster speed of transfer between the patterns regardless of gender factor.

Key words: Bimanual coordination, Cognitive load, Transfer phase, Gender, Elderly.

The capability to perform just about every motor performance task diminishes with advancing age. In fact, older adults are slower with advancing age, and tend to trade off speed for accuracy[1]. Aging causes a gradual degeneration of the neuromuscular system and cutaneous sensation [2-4]. These physiologic changes affect the functional performance of the hands of the elderly population[2, 5] and a decline in the regulating and controlling capacity with fine motor control[5]. Because of changes in physiological and functional conditions, elderlies are unable to give appropriate responses suitable to cope with manipulation of objects including complex bimanual hand functions and bimanual catching[4, 6]. The proportion of affected daily activities reportedly varies between 13% and 35% in the elderly population[7]. With aging, decrease in bimanual coordination in discrete and continuous task occurs probably due to different control mechanism for temporal coupling of limbs. Inter limb timing is a skill that healthy humans perform in activities of daily living from very early in childhood and that they continue to perform until late in life[1]. Degeneration in the neuromuscular system due to aging can affect daily activities that need to be controlled by bimanual coordination with both hands. However, little is known about the influence of aging on grip strength and

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bimanual coordination control between hands[8]. Despite the fact that aging is a condition characterized by a general decline in many types of physical and psychological performance, however, its effects on various cognitive functions are still controversial. Among psychological functioning in the elderly, changes in attention are not fully understood[9].

Generally, bimanual coordination is determined by different types of constraint including temporal, spatial and muscle grouping[10, 11]. In-phase pattern (0p relative phase) in which both hands move with the same relative velocity is more stable compared to anti-phase pattern (180p relative phase). For spatial constraints, isodirectionality in extrinsic space generally results in better performance than non-isodirectionality[12]. Muscle grouping refers to the body's natural preference to co-activate homologous muscles, giving rise to the symmetrical or in-phase mode being the most favorable state, and the asymmetrical or anti-phase mode being less stable[12, 13]. An instance of anti-phase pattern is walking. In this instance, there is one temporal alternate for the feet[14]. In the face of these constraints, converging evidence suggests an age-related progressive decline in bimanual coordination and response switching performance[15, 16]. A convenient and powerful laboratory task to explore temporal coordination as a function of age involves continuous movements of the upper limbs[17]. In the performance of these coordination tasks, previous research has shown that the older adults perform the in-phase pattern as well as younger adults but show deficits in the anti-phase pattern at relatively high metronome pacing frequencies [18].

performance capability for some motor skills declines rapidly with advancing age but that other motor skills show little or no decline at all is of theoretical interest. One hypothesis for the absence of age-related differences is that temporal coordination represents a type of generalized motor skill that is less susceptible to aging effects than other types of motor skills. This hypothesis is unlikely to be true, however, as other patterns of temporal coordination (i.e., other than in-phase or anti-phase) show very large age-related differences. Only for the in-phase pattern and the anti-phase pattern (at slow-pacing frequencies) has there been an absence of age-related differences found in bimanual coordination performance[17].

Two alternative hypotheses were explored to account for the absence of age-related differences in bimanual coordination. One hypothesis was that older adults perform as well as younger adults on these patterns because they allocate more attention to the performance of the task. This attention allocation hypothesis posits that coordination performance is within the limits of available attentional resources for both younger and older adults, but that older adults must access more of these resources in order to achieve a level of performance that the younger adults achieve with less allocation of attention. Further, it is only when the task demands exceed the older adults' available attention resources that age-related differences in performance arise. The other hypothesis examined here is that these temporal-coordination tasks are highly over-learned, likely due to the fact that they have been "practiced" over a lifetime of actions requiring such coordination. In the experiment performed by Lee and associates (2002), this hypothesis was tested by using a bimanual coordinating task (in-phase and anti-phase) in two frequencies of 1 and 2 hertz. The result of this research confirmed both hypotheses. The automaticity view was supported only for the coordination patterns at the 1 Hz metronome frequency, whereas the hypothesis of attention allocation was confirmed in the higher frequency task. Older adults tended to sacrifice movement frequency at the 2 Hz metronome pace in order to maintain performance in the movement and counting tasks[1].

When coordinated bimanual rhythmic movements are asymmetric, they become difficult to perform and are often characterized by a high degree of interference based on the coordinating tendencies of the limbs[19]. Across a range of rhythmic movements, our limbs naturally tend to adopt identical, or symmetric, roles. Breaking that tendency requires a great deal of effort and attention[20]. a pattern switching is preceded by an increase in the variability of relative phase as oscillation frequency rises, and these fluctuations subsequently decrease after the transition. This conclusion leads to two assumptions. First,

maintaining the pattern before and after transition may be associated with increasing and decreasing the energetic cost necessitated to perform the coordination patterns. Second, pattern stability (and hence, phase transition) may be affected by cognitive processes such as intention and attention. In addition, applying the focus of attention instruction in bimanual coordination pattern may significantly alter the transfer phase[21]. Recently, researches have been designed to examine the relationship between the bimanual coordination and gender and the change associated with age. For instance, Ashwini and associates (2014) showed that males have better bimanual coordination when compared to their female counterparts and aging causes decline in efficiency of bimanual coordination[22]. Bangert and associates (2010), Bellis and Wilber (2001), and Muetzel and associates (2008) have stated that producing coordinated two-handed movements requires precise timing between the limbs which is influenced by various factors like age, handedness and gender[23-25]. Moradi and Heyrani (2012) examined the relationship between bimanual coordination and gender in three age groups of young, middle andold age groups. The result of this research showed that in older women group, they performed the task better than their men counterparts. Thus, they concluded that gender is a significant factor that influence bimanual coordination tasks[26].Considering the presence of different hypothesis about the attention limitations regarding the age on bimanual coordination tasks and conflicting results reported about the cognitive loading of attention, there is a need to examine these hypothesis in more researches.Therefore, this research was designed to determine whether introducing cognitive loading in bimanual coordination results in change of anti-phase pattern to in-phase pattern in men and women. In this way, it is possible to show if the presence or absence of cognitive loading in men and women has any effect on the moment of disruption attractor's patterns and transfer between these patterns.

Research methodology

Participants

In this experimental design, 10 male and 10 female individuals with the mean age of 63 years old participated voluntarily. The participants were healthy right-handed who had no visual or hearing impairments. In addition, they were free from any neuro-muscular problems.

Instrument and task

The instrument employed in this research included

Bimanual coordinating apparatus: this set is made by Padidar-OmidFarda cultural and sport institute of development and technology center of Shahid Beheshti University to record movement data. The validity of the instrument is assessed through the correlation method. There was a correlation of 0.81 between the scores of the participants recorded by Viennabimanual coordinationset and linear movement set. In addition, the reliability of the set was assessed through the test-retest method (r=0.90)[27]. The aforementioned includes two parts: software and hardware. The hardware is scaled from -90 to +90 degree regardless of negative sign for the in-phase and anti-phase pattern of movement for both wrists.

An auditory metronome that provided step to step information for performing coordination

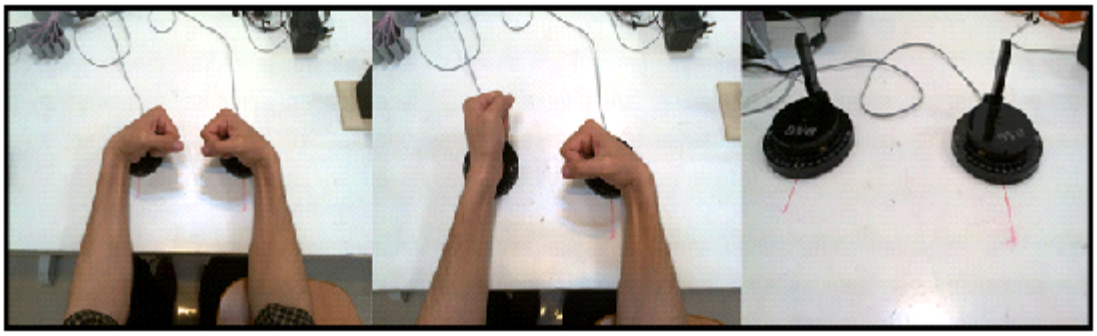

Photo 1. bimanual coordination set of wrist for measuring in-phase and anti-phase pattern

patterns and by it the speed of movement was increased gradually.

Procedures

Following the contact with the senior citizen of Saraye-mahallehVelenjak-Tehran and receiving permission to conduct the study in the institute, 20 volunteer senior citizens were selected. The inclusion criterion included the volunteers that were free from hearing and vision impairment and had no neuro-muscular disorders. The participants received instruction about the task. The participants were required to sit behind the apparatus, hold the handles connected to the set and move it horizontally to left and right. They were sitting on an adjustable sit while holding the handles and performed the 180 degree relative phase (anti-phase pattern). The anti-phase pattern was performed when one of the wrists was flexed while the other one was extended. The participants were trained to move and regulate their movement according to a metronome ticks. Thus, the speed of movement was changed based on the rhythm of metronome. The metronome rhythm required the participants to move the limbs with low speed (frequency 0f 0.5 hertz) initially. During the execution of the task, the frequency was gradually increased from 0.5 to 3 hertz in such a condition that 0.25 hertz per 5 second was added to increase the speed(frequency amplitude was calculated based on pilot research). The participants were encouraged to keep the best pattern of timingof bimanual coordination movement set by metronome. Therefore, the coordination timing was the first priority and they did not receive any advice for remaining in anti-phase. This task was performed with and without the inverse counting for every participant. The participants continued to perform the task until anti-phase pattern was disrupted and it changed to in-phase pattern. A rest interval as long as the time to perform the task between the two different conditions was given.

Analysis

Relative timing of both limbs was calculated by Matlab software and transfer time and speed at the moment of transfer was also measured by the same procedure. Descriptive statistics including mean and standard deviation were calculated for the gender and cognitive

Table 1. Mean and standard deviation of scores according to gender and cognitive loading

Gender	M±SD(Transfer time)		M±SD(Transfer frequency)	
female	Secondary task	13.58±17.734	Secondary task	0.75±1.25
	No- Secondary task	18.17±37.103	No- Secondary task	0.89±2.17
male	Secondary task	16.77±28.501	Secondary task	0.87±1.8
	No- Secondary task	16.26±48.229	No- Secondary task	0.87±2.8

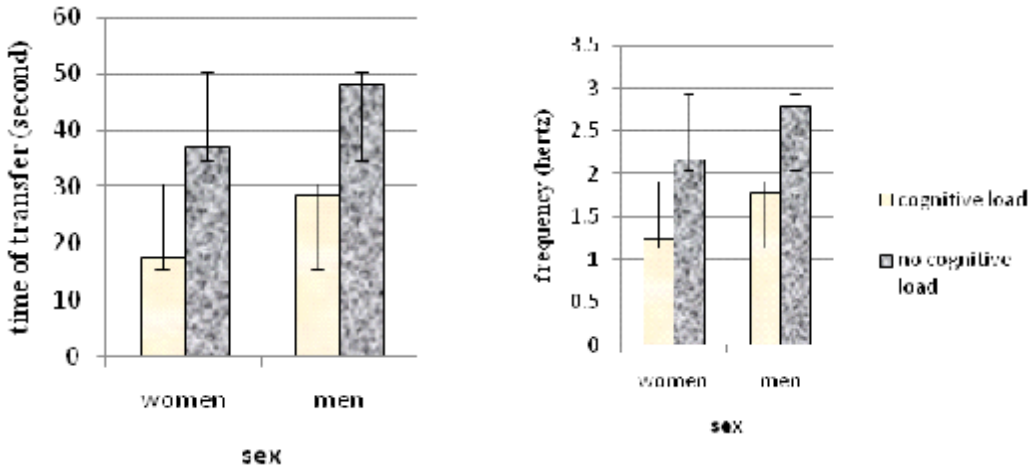

Fig. 2. Time of transfer and frequency with and without cognitive loading for male and female participants

loading. These results are presented in table 1. Factorial analysis of variance was employed to examine the gender and cognitive loading differences. All hypotheses were tested at alpha level set to 0.05.

RESULTS

For the purpose of analyzing data, variables of time of transfer and speedat the moment of transfer from anti-phase to in-phase were determined. The result of Kolmogrov-smironov test indicated that data were normally distributed (P=0.1).

A visual inspection of the figure reveals that the time of transfer and frequency with and without cognitive loading for male and female participants is different. A 2 by 2 factorial ANOVA indicated that cognitive loading had a significant effect ($F_{(1.18)}$ = 31.790, P=0.001). However, the main effect of gender was not significant ($F_{(1.18)}$ = 2.934, P<0.05). In addition, there was no significant interaction between the gender and cognitive loading ($F_{(1.18)}$ = 0.003, P>0.05).

DISCUSSION AND CONCLUSION

The purpose of the present research was to examine the effect of cognitive loading and gender on the pattern of bimanual coordination performance. The time of transfer from anti-phase to in-phase and the frequency that causes this change in men and women during the cognitive loading or absence of such condition was studied. Based on the result of analysis, cognitive loading had a significant effect on shortening of resistance time when the speed was increased and finally it was transferred from anti-phase to in-phase. The dynamic systems view purposes that a single program created by the central command system cannot be in control of all the variations and adjustments needed in a skilled performance. According to this view, movements are the product of dynamic interaction of different variables involved in body, environment and the task in hand or they are self-organized.These variables constantly impose constraints on the movement. Thus, motor pattern emerged is the product of these constraints. The body constraintsinclude variables such as anthropometrical, biomechanical, cognitive and emotional conditions. The environmental constraints are variables such as gravity force, environment temperature, and the surface where the acts are performed. The task restrictors include intention, goal, machinery, instruments and tools involved in the act that need manipulation such as bolls and rockets in sports (29).

The findings of this study support the dynamic systems view. As the task and the individual factor changed, the task became more difficult and this condition led to disturbance in motor pattern and the new pattern is performed through self-organization. The more difficult the task, the faster the individual turns to transfer stage. The result of this study is in agreement with the findings of Lee and associates (2002) who ask their subjects to perform a task requiring bimanual coordination (in-phase and anti-phase) in frequency of 1 and 2 hertz. The result of their research supported the both hypothesis of automaticity and attention allocation. older adults tended to sacrifice movement frequency at the 2 Hz metronome pace in order to maintain performance in the movement and counting tasks. The main difference of the present research compared to the one conducted by Lee (2002) lies in the speed employed in the task. In the present research, the speed was increases continuously. This condition results in increase in precision and gradual increase causes adjustment to speed. Thus, changes are not due to deficiency in adjustment to the new speed. In the research conducted by Lee *et al* (2002), the view for the automaticity of coordination pattern in frequency of 2 hertz was not confirmed. This finding is also similar to what was found in the present research. It was found that practiced bimanual coordination was also faced with attention limitation.

In a research conducted by Monno and associates (2000), the effect of attention on transfer phase between the patterns of coordination was examined. In this research, the cost of increase in frequency with the secondary task was assessed by reaction time. The result of this research indicated that prior to the transfer phase, the cost of performing the task increases and after the transfer phase, the costs decreases. In case of increase in the cost of performing the task with increase in frequency, introducing the secondary

task of reverse counting places more load on the central system. Therefore, this result is also similar to the result of the present research. In other hand, Monno et.al. pinpointed to the fact that having appropriate focus of attention delays the transfer phase. In the present research, there was no instruction for the focus of attention to examine the effect of the secondary task. The finding of the present research is not in agreement with the findings of Farsi and associates (2011)(29). These authors compared the effect of attention and motor cognitive loadings on performance of a bimanual coordination task and did not find significant difference between the cognitive loading groups and the control group. The participants in that research were young individuals whereas the participants in the present research were elderly. Commodari and Guarnera (2008) stated that the elderly group face deficiencies in some aspects of attention control and this may be a reason for finding contradictory results.

In the present research, no significant difference was found between the male and female participants. Ashwini and associates (2014) demonstrated that bimanual coordination in elderly male group performed the task better than their female counterparts[22]. Moradi and Heyrani (2012) examined the effect of sex on continuous bimanual coordination in three different groups including young, middle and old age groups. The result of this research showed that women in the elderly group demonstrated a better performance compared to the men; thus concluded that gender is a significant variable in performing motor patterns that coordination has a role. That result is not in agreement with the findings of the present research. These contradictory findings may be attributed to the degree of freedom involved in the tasks. Langolf and associates (1976) demonstrated that larger limb and slower ones (e.g., arm) have higher sensitivity relative to the change in task difficulty compared to smaller parts such as finger (30). Based on these findings, the more joints are involved in the movement, the more degree of freedoms to control and the more difficult the task becomes. In the present research, the task involved the movements of wrist joint whereas in the task used by Moradi and Heyrani (2012) other joints including elbow and shoulder. One of the likely reasons for findings the discrepancy in men and women performance is this difference. In case more joints were involved in the present research, probably the difference in gender performance may have disappeared.

Finally, considering the role gender as a significant variable on bimanual coordination and the likelihood of degree of freedom effect on these motor patters, future research are needed to examine the changes in gross motor patterns. In addition, due to the effect of ageing on bimanual coordination, it is necessary to examine the issue in different age groups.

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