109 - CONTROL STRATEGY IN CYCLICAL AND DISCRETE MOVEMENTS IN FITTS' TASK ADAPTED FOR VIRTUAL ENVIRONMENT

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INTRODUCTION

The inversely proportional relation between speed and precision in control of ballistic movements of touch in space targets is called Fitts' Law (Teixeira, 1997). This law may be found in different contexts and sports skills, so that when a task is performed with great speed tends to decrease the accuracy and, inversely, when there is an increase of the precision the speed is reduced in order to achieve the success of the movement. Fitts (1954) demonstrated, by experiments manipulating the size of the targets (L) and the distance between them (D), that the movement time (MT) is a linear function of the index of difficulty (ID) of movement, which is expressed by the equation: ID = log2 (2D / L). Thus, an increase in ID generates a proportional increase in the MT. Although this inverse relation between speed and accuracy is one of the most consistent phenomena in the field of motor behavior, it is still not understood about the specific effects of the task constraints on movement regulation, for example, perform the same task cyclically and discretely .

Control strategies are influenced by the specific constraints of the different types of motor skills. Thus, Fitts and Peterson (1964) presented a performance disadvantage of cyclical movements due to the specification of control parameters occurred during the movement. This process is called partial parallelism and would not be present in the performance of discrete movements in which it would be possible to anticipate the specifications of the control parameters (feedforward). Thus, the discrete movements would be performed with a lower MT for being processed with anticipation, while the cyclical movements would need extra time to process the feedback information. Despite the advantages presented above, Guiard (1997) suggests that the cyclical movements would present a mechanical advantage as they allow storing and reusing the mechanical energy, providing dynamic advantages due the effector system characteristics. However, in the discrete movements the energy tends to be dissipated at the end of the task. Thus, the regulation of discrete and cyclical movements provides specific restrictions because they are regulated by particular strategies.

Smits-Engelsman, Swinnen and Duysens (2006) also reported that the speed-accuracy relation is different for both kind of movement, and that, in cyclical movements the speed can be increased twice as more than in discrete movement to see the same decrease in accuracy.

Given the above, this study analyzed the control strategies of discrete and cyclical movements in the Fitts' task simulated in a virtual environment. Thus, were raised the following hypotheses: 1) the MT will present a linear relation with the ID in both movements, so that, with an increase of the ID will occur an increase in MT and 2) due to the mechanical advantage of cyclical movements, cited by Guiard (1997), the MT of the conditions with cyclical movements will be shorter than the times of the conditions with discrete movements.

METHODS

The study included 15 individuals of both sexes, aged between 15 and 30 years. These participants were informed of the evaluation procedures and signed an informed consent. This study was approved by the ethics committee of the local university (Process n. 215/10; CAAE n. 0197.0.268.000-10).

It was used in the experiment, the software Discrete Aiming Task (v.2.0) (Okazaki, 2007), in which the Fitt's law was simulated in a virtual environment. The task consisted of clickin in two parallel bars (buttons) with the left button of the mouse arranged on the computer screen, as quickly and accurately as possible. These buttons were handled according to their size (L = 2, 1, 0.5 and 0.25 inches) and kept at a distance of 4 inches in all conditions. Thus, the index of difficulty (ID) in the task was 2, 3, 4 and 5 bits, respectively.

Participants were positioned seated in a chair in front of a laptop, so that the computer's screen was at eye level. Then, there were eight experimental conditions, four discrete movements (a movement from one target to another) in different ID (D2, D3, D4 and D5) and four cyclical movements (four movements of a target to another) in different ID (C2, C3, C4 and C5). Initially, we performed a familiarization trial in each experimental condition. Subsequently, participants performed four consecutive trials in each condition with a randomized sequence between participants.

The independent variables of this study were: the type of movement performed (discrete and cyclical) and the index of difficulty (2, 3, 4 and 5 bits). The dependent variable used to analyze the movement was movement time (MT). The data was analyzed with the software Statistica (v.7) by means of nonparametric statistics, because they have been violated the assumptions of normality. We used the Friedman ANOVA and for subsequent comparisons, the Wilcoxon paired test. The level of significance in the statistical analysis was $P<0.05$.

RESULTS

The results showed an increase of MT due to the increase in ID ($P<0.01$), as shown in figure 1, confirming a direct linear relation between MT and ID. These results supported the first hypothesis of the study. Thus, the findings corroborate the Fitts' Law, regardless of the movement to be discrete or cyclical. The performance of cyclical movements in the task was similar to the task performance of discrete movements in all the IDs, so the Wilcoxon paired test showed no difference in scores for MT ($P>0.06$).

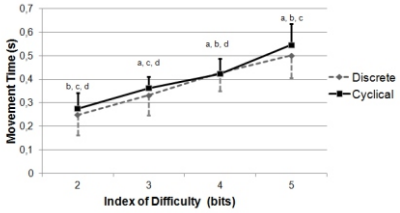

Figure 1. Mean and standard deviation (vertical bars) of the movement time as a function of index of difficulty for discrete and cyclical movements.

Legend: significant difference (P<0.05) when compared to ID a2, b3, c4, d5.

Comparisons were made between the MT of the participants in the different IDs in a discrete task and cyclical task, and it was found significant difference only in the factor ID (P<0.001), but there was no interaction between the indices of difficulty and tasks (P>0.05). The significant difference observed between the IDs only occurred within the same task (P<0.05). These results did not confirm the second hypothesis of the study, which predicted that participants would have better performance on the cyclical task compared with the discrete.

Table 1.Differences in performance between the IDs for discrete and cyclical movement.

	Movement Time (s)	
ID (bits)	Discrete Movement	Cyclical Movement
2	0,24 (3,4,5)	0,28 (3,4,5)
3	0,33 (2,3,5)	0,36 (2,4,5)
4	0,43 (2,3,5)	0,42 (2,3,5)
5	0,50 (2,3,4)	0,55 (2,3,4)

Legend: numbers (2,3,4and 5)represent significant difference (P<0.05) for the IDs in the same condition of motion.

DISCUSSION

This study examined control strategies through the analysis of movement time, in performing discrete and cyclical movements, within the paradigm of Fitts. We raised two hypotheses based on these approaches in the study of motor control. The first hypothesis suggests that the MT would show a linear relation with the ID, in other words, the MT would increase with an increase of the ID. The second hypothesis suggests that the cyclical movements would present a MT shorter than discrete movements, due to a mechanical advantage, cited by Guiard (1997). These hypotheses were analyzed using the Fitts' task simulated in a virtual environment.

The results showed an inverse relation between speed, accuracy, since, with the increase of the ID the MT also increased, confirming the first hypothesis. However, the results showed no difference in performance between the discrete and cyclical movements, not confirming the second hypothesis. Therefore, these results did not support the notion of superior performance by performing cyclical movements due the mechanics of movement, unlike the findings of Guiard (1997).

Guiard (1997) showed that as the ID was greater there would be a higher performance of the discrete movement over the cyclic movement, since a new programming would be required for each movement that is repeated. However, in lower IDs, the cyclical movement would be made in a shorter MT, resulting in greater acceleration towards the next move. The use of a mechanical energy to continue the movement, which could maximize performance and allow a lower movement time, in the case of cyclic task, seems not to have occurred in the performance of the participants of this study.

In Smits-Engelsman, Swinnen and Duysens's (2006) study, the inverse relation between speed-accuracy was investigated manipulating the size, the target distance and the weight insertion in the hand as a constraint of the task. The authors confirmed the hypotheses of superiority in the cyclical movement performance, remaining the advantage even if the amplitude of the movement changed. This result was explained by the shortening-stretching muscular function that provides elastic strength to the muscle to continue the movement, which corroborates the proposition of uiard (1997) about the mechanical advantage of the movement in a cyclic task. It was also confirmed in this study the straight of the performance in cyclical movement in a loaded condition, as a task constraint. In other words, the load did not affect the pace of the task of pointing cyclic, and that the frequency of the movement did not differ in the conditions with load and without load. The results were discussed based in explanation of the neural functioning to the movement control in cyclical and discrete actions, similar to the functioning of the central pattern generator in a walking movement.

In this study, it is considered that a secondary constraint could have influenced the task performance. In the study cited by Smits-Engelsman, Swinnen and Duysens (2006) the task was performed in a digital tablet using as an instrument the pen itself, whereas in this study that aimed to analyze the control strategies in virtual environment, the participants used the mouse and its left button to click the target as they could view the movement on the computer screen. As there were no differences in performance between the discrete and cyclical movements, a possible explanation might be related to the use of materials that provide different movements constraints, in this case, the mouse seems not to have allowed the mechanical advantage for the cyclical movements, as it seems to happen when a pen is used.

CONCLUSION

No significant differences were verified in performance between the discrete and cyclical movements, showing only difference between the IDs within a single task. However, the inverse relation between speed-accuracy was found in the present study, demonstrating the robustness of Fitts' Law. Thus, it is suggested that further studies comparing discrete and cyclical movements, both in real environments and in virtual environments. For this, the analysis of movement through kinemetry allow the evaluation of motor control used in the regulation of different strategies of movement, and the performance comparison involving different instruments in the performance of the task.

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CONTROL STRATEGY IN CYCLICAL AND DISCRETE MOVEMENTS IN FITTS' TASK ADAPTED FOR VIRTUAL ENVIRONMENT

ABSTRACT

This study examined the strategies of control of discrete and cyclical movements in the Fitts' task simulated in a virtual environment. For this, participated in the study 15 individuals of both sexes, aged between 17 and 30. The software Discrete Aiming Task v. 2.0 (Okazaki, 2007) simulated the Fitts' task in the discrete and cyclical conditions providing the movement time (MT). Thus, the participants performed movements clicking the left mouse button on parallel bars, with a size of 2, 1, 0.5 and 0.25 inches, kept at a distance of 4 inches of each other, performing as quickly and accurately as possible. The index of difficulty (ID) in the task accomplished were 2, 3, 4 e 5 bits, respectively. Thus, we conducted eight experimental conditions, four of discrete movements (D2, D3, D4 and D5) and four of cyclical movements (C2, C3, C4 and C5). Four trials in each condition were performed in a randomized sequence. . Data were analyzed by Friedman`s ANOVA and subsequent comparisons with Wilcoxon paired test. For significance level was adopted P<0.05. There was no significant difference in the MT scores between the discrete and cyclical movements. But the increase in the ID caused an increase in the MT, showing an inverse relation between speed and accuracy. Thus, Fitts' Law demonstrated robustness regardless of the type of movement, discrete or cyclical.

KEY-WORDS: Motor control, Fitts' Law, discrete and cyclical movements.

LES STRATÉGIES DE CONTRÔLE DES MOUVEMENTS CYCLIQUES ET TÂCHE DE FITTS DISCRET EN MILIEU ADAPTÉ POUR VIRTUEL

RÉSUMÉ

Cette étude a examine lês stratégies dês mouvements controle discret et cyclique dans latâche de Fitts simule dans un environnement virtuel. À cettefin, 15 personnes ont participé à l'étude, dês deux sexes, âgés entre 17 et 30 ans. Le logiciel Discrete Aiming Task v. 2.0 (Okazaki, 2007) simulé les conditions dans la tâche de Fitts du discret et cyclique, en fournissant les temps de mouvement (TM). Ainsi, les participants ont effectué des mouvements de cliquer sur le bouton gauche de la souris sur les barres parallèles, avec une taille de pouces 2, 1, 0,5 et 0,25, maintenu à une distance de 4 pouces les unes des autres, avec plus de rapidité et de précision possibles. Les indices de difficulté (ID) dans l'accomplissement de la tâche ont été de 2, 3, 4 et 5 bits, respectivement. Ainsi, il y avait huit conditions expérimentales, quatre mouvements discrets (D2, D3, D4 et D5) et quatre des mouvements cycliques (C2, C3, C4 et C5). Ont été 4 essais menés dans chaque condition en séquense aléatoire. Les données on tété analysées par ANOVA de Friedman et des comparaisons ultérieures avec le test de Wilcoxon paires appariées. Nous avons adopté un niveau de signification de p<0,05. Il n'y avait pas de différence significative dans les scores entre les mouvements TM discret et cyclique. Mais l'augmentation des ID causer une augmentation de MC, montrant la relation inverse entre la vitesse et la précision. Ainsi, la loi de Fitts a montré la force, indépendamment du type de mouvement, discrètes ou cycliques.

MOTS-CLES: Controle moteur, La loi de Fitts, dês mouvements discrets et cycliques.

ESTRATEGIAS DE CONTROL EN LOS MOVIMIENTOS CÍCLICOS Y DISCRETOS EN LA TAREA DE FITTS ADAPTADA PARA EL MEDIO AMBIENTE VIRTUAL

RESUMEN

Este estudio examinó las estrategias de los movimientos de control discreto y cíclico en la tarea de Fitts simulados en un ambiente virtual. Para eso, 15 personas participaron en el estudio, de ambos sexos, con edades comprendidas entre 17 y 30 años. El software Discrete Aiming Task v.2.0 (Okazaki, 2007) simuló las condiciones discreta y cíclica en la tarea de Fitts, proporcionando el tiempo de movimiento (TM). Así, los participantes realizar on movimientos de clic en el botón izquierdo del ratón sobre las tabletas paralelas, con un tamaño de 2, 1, 0,5 y 0,25 pulgadas, mantenidas a una distancia de 4 pulgadas el uno del otro, con mayor velocidad y precisión sea posible. Los índices de dificultad (ID) en el cumplimiento de la tarea fueron 2, 3, 4 y 5 bits, respectivamente. Así, había ocho condiciones experimentales, cuatro movimientos discretos (D2, D3, D4 y D5) y cuatro de los movimientos cíclicos (C2, C3, C4 y C5). 4 ensayos se realizaron en cada condición en secuencia aleatoria. Los datos fueron analizados por ANOVA de Friedman y las comparaciones posteriores con la prueba de pares de Wilcoxon. Fué adoptado un nivel de significación de p<0,05. No hubo diferencias significativas en las puntuaciones del TM entre los movimientos discretos y cíclicos. Sin embargo, el aumento del ID causó un aumento del TM, que señala la relación inversa entre la velocidad y precisión. Así, la Ley de Fitts ha demostrado la fuerza, independientemente del tipo de movimiento, discreto o cíclico.

PALABRAS-CLAVE: Control del movimiento, La ley de Fitts, los movimientos discretos y los movimientos cíclicos

ESTRATÉGIA DE CONTROLE EM MOVIMENTOS CÍCLICOS E DISCRETOS EM TAREFA DE FITTS ADAPTADA PARA AMBIENTE VIRTUAL

RESUMO

Este estudo analisou as estratégias de controle de movimentos discretos e cíclicos na tarefa de Fitts simulada em ambiente virtual. Para tal, participaram do estudo 15 indivíduos, de ambos os sexos, com idade entre 17 e 30 anos. O software Discrete Aiming Task v.2.0 (OKAZAKI, 2007) simulou a tarefa de Fitts nas condições discreta e cíclica, fornecendo o tempo de movimento (TM). Assim, os participantes realizaram movimentos de clicar com o botão esquerdo do mouse em barras paralelas, com tamanho de 2, 1, 0,5 e 0,25 polegadas, mantidas a distância de 4 polegadas uma da outra, com a maior rapidez e precisão possível. Os Índices de Dificuldades (ID) na realização da tarefa foram de 2, 3, 4 e 5 bits, respectivamente. Desta forma, foram realizadas oito condições experimentais, sendo quatro de movimentos discretos (D2, D3, D4 e D5) e quatro de movimentos cíclicos (C2, C3, C4 e C5). Foram realizadas 4 tentativas em cada condição, em sequência aleatorizada. Os dados foram analisados por meio da ANOVA de Friedman e as comparações posteriores com o teste pareado de Wilcoxon. Foi adotado o nível de significância de P<0,05. Não houve diferença significativa nos escores de TM entre os movimentos discretos e cíclicos. Mas, o aumento do ID ocasionou aumento no TM, demonstrando a relação inversa entre velocidade e precisão. Portanto, a Lei de Fitts demonstrou robustez, independente do tipo de movimento, discreto ou cíclico.

PALAVRAS-CHAVE: Controle Motor, Lei de Fitts, Movimentos discretos e cíclicos.