行政院國家科學委員會專題研究計畫 成果報告

預期性控制對平衡反應時間的影響：發展中風疾患出院準備之平衡訓練(第 2 年)
研究成果報告(完整版)

計 畫 類 別 ：個別型
計 畫 編 號 ：NSC 96-2314-B-040-003-MY2
執 行 期 間 ：96 年 08 月 01 日至 98 年 07 月 31 日
執 行 單 位 ：中山醫學大學物理治療學系

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報 告 附 件 ：出席國際會議研究心得報告及發表論文

處 理 方 式 ：本計畫可公開查詢

中 華 民 國 98 年 08 月 06 日

行政院國家科學委員會補助專題研究計畫　　□ 成果報告 □期中進度報告

（計畫名稱）

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計畫類別：□ 個別型計畫 □ 整合型計畫

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計畫參與人員：

成果報告類型(依經費核定清單規定繳交)：□精簡報告 □完整報告

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執行單位：中山醫學大學物理治療學系

中 華 民 國 2009 年 07 月 28 日

（一） 中文摘要。

可預期的平衡干擾實驗設計可以提供一個研究人體平衡控制之預期因子的窗口，過去研究發現雖然平衡干擾的強度或方向是可預期的，反應時間仍然不可改變。為了要深入探究平衡干擾發生時間之可預期性對於反應時間的影響，本研究設計了一連串的發生時間規律的平衡干擾，以對比一連串的發生時間不規律的平衡干擾。除了時間之可預期性之外，本研究設計也探討平衡干擾發生方向之可預期性。在兩個實驗中，十位健康老人以及十二位健康年輕人分別接受二十公厘的側向臚部平衡干擾，平衡干擾由自行研發之電腦與馬達系統控制。我們發現不可預期發生時間的平衡干擾有較短的反應時間，平衡干擾發生方向之可預期性不對反應時間產生影響，也沒有發生時間與方向之可預期性的交互作用。本研究結果證實了人體平衡反應時間之可操弄性。我們也討論了不可預期發生時間的平衡干擾所導致的較短反應時間，可能是由於挑戰性不高的平衡干擾強度造成警覺度在不可預期發生時間的實驗狀況中較高。

（二） 英文摘要。

Designing paradigms with predictable disturbances to balance allows study of anticipatory factors in the control of postural responses. Previous research showed that response time was independent of prior information regarding the magnitude or orientation of the upcoming disturbance. In order to probe the effects of temporal predictability on postural response time in standing balance, this study identified a balance perturbation paradigm with a regularly spaced series of perturbations. This was contrasted with conditions in which perturbations were introduced in random timing. In addition to the variable of timing certainty, another variable of direction certainty was factorially added - directed alternately to right and left or randomly. In Experiments 1 and 2, a computer-controlled actuator system applied horizontal displacements of 20-mm to hip of ten elderly and twelve young participants respectively. By using discrete timing methods we revealed that the temporally unpredictable perturbations resulted in a shorter response time. Neither effect of direction certainty nor interaction effect was shown. These results evidenced the manipulability of postural response time. The shorter response time with temporally unpredictable perturbations was discussed in terms of heightened alertness, given that non-threatening magnitudes of disturbance were applied.

壹、報告內容

一、前言

Self-induced perturbations to balance due to voluntary movement are typically compensated much earlier with anticipatory postural adjustments [7] than are externally imposed perturbations such as support translation [22]. This may be understood because the central nervous system is able to predict the consequences of making a voluntary movement, but not the effects of unexpected external perturbations [21]. However, it may be observed that imposed perturbations to balance can vary in their degree of predictability, in which case earlier compensation might be expected when conditions allow a greater degree of prediction.

Previously, researchers have adopted various paradigms to evaluate predictive contributions to the control of postural responses that are elicited by external threats [4;5;11;12;15;17;19;20;23]. These include blocked paradigms, in which imposed force perturbations of the same characteristics are arranged in a block [6;10;14;16;18;23] and cueing paradigms, providing visual or verbal cues about the characteristics of the forthcoming perturbation [3;12;20]. Although such studies have advanced our understanding of coordination in standing balance, the response time to the onset of the postural response is generally found to be invariant regardless of prior information provided about the magnitude or orientation of the next perturbation.

二、研究目的

In this study we identified a new computer-controlled actuator system, as well as a new paradigm involving periodic perturbations, by which we investigate effects of temporal predictability on postural response time.

三、研究方法

A computer-controlled actuator system (FUJI- GYS 101DC1), which could provide linear thrust of up to ±200 N over a distance of ±100 mm at a maximum speed of 400 mm/s was built up for this study (Fig. 1). Postural responses were elicited by the actuator applying horizontal displacements of 20 mm to the pelvis. In one condition, the temporal interval of a series of hip displacements was set at 1500 ms, and participants could expect the next perturbation to occur after 50 ms following a metronome beat. This condition of predictable timing was contrasted with an unpredictable timing

condition, in which a metronome of 1500-ms intervals was also played but perturbations were introduced in random timing (range of intervals: 1000~2000 ms, average 1500 ± 320.16 ms). Another variable of direction certainty was factorially added with the variable of timing certainty.

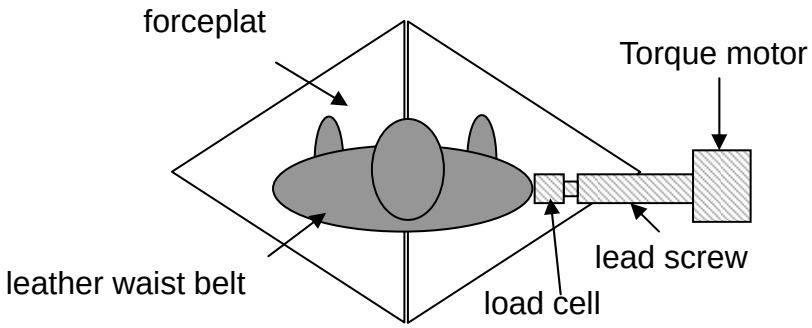

Fig. 1. Illustrated design in Experiments 1 & 2, showing a computer-controlled actuator system. The actuator, consisted of a torque motor fitted with a lead screw, was coupled via a load cell to the side of a waist belt. Postural responses were elicited by the actuator applying horizontal displacements to the tightly fitting waist belt, while the load cell measured the perturbing forces. Two forceplates recorded ground reaction forces.

This paradigm was tested in neurologically normal elders (8 female and 2 male, aged 70.3 ± 5.2 years, body height 155.9 ± 5.9 cm) in Experiment 1, and young adults (7 female and 5 male, aged 21.8 ± 4.0 years, body height 164.3 ± 11.0 cm) in Experiment 2. Four of the elders experienced one fall during the past six months, whereas no other participants reported previous accidental fall. All of the elders had scores of the Berg Balance Scale greater than 49, with an average of 53.5 ± 2.6. Each participant provided written informed consent. After taking off their shoes and socks, participants stood comfortably with a consistent feet position throughout the experiment. Participants were instructed to look straight ahead and to resist the perturbations in a symmetric stance, but avoid moving their arms or feet. In each condition, there were three 60-second trials, preceded by one 30-second practice trial.

GRFs and perturbation forces were recorded at 200 Hz by two forceplates (UTE- Model UEA 200) and a load cell (interface- SM 200N). Responses were off-line segmented, and only responses to odd perturbations were analyzed. The analyses involved, firstly, a discrete timing method for response time of lateral COP relative to onset of perturbing force, using fully automated algorithms of 5 SD above baseline. In this analysis, responses to right and to left perturbations were pooled

together. The analyses involved, secondly, the average position of lateral COP in the 50-ms interval prior to each perturbation.

四、結果與討論（含結論與建議）

Results for response time, from running the discrete timing methods in Experiments 1 and 2, are shown in Fig. 2. ANOVA tests resulted in main effects of timing certainty ($F(1,9) = 4.698$, $p = .058$)($F(1,11) = 7.579$, $p = .019$). Specifically, response time to perturbations with unpredictable timing was shorter than that with predictable timing. Tendency for a main effect of direction certainty as shown in Fig. did not reach significance ($F(1,9) = 1.991$, $p = .192$)($F(1,11) = 2.934$, $p = .115$). There was no interaction effect ($F(1,9) = .873$, $p = .374$)($F(1,11) = .511$, $p = .49$).

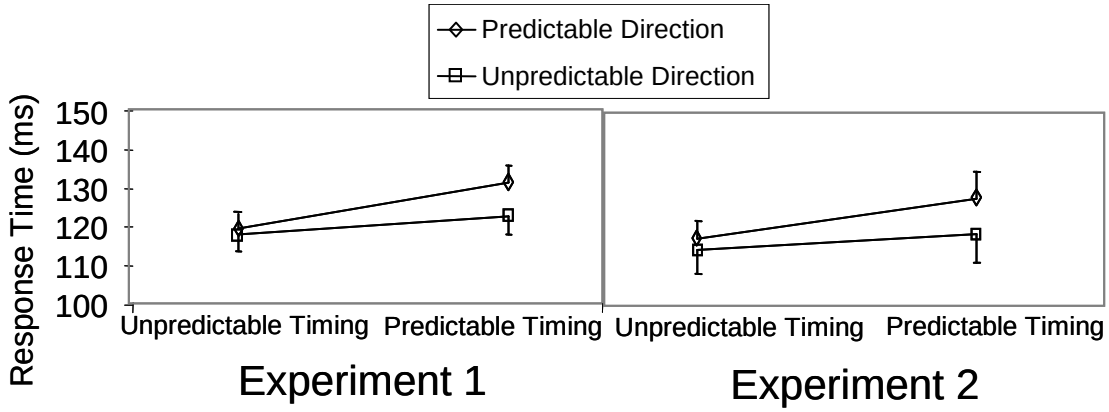

Fig. 2. Response time, extracted from discrete timing methods between lateral COP and perturbing force, in the four conditions as factorial combinations of two levels of timing and direction certainty in Experiments 1(N=10), and 2(N=12). One standard error bar is indicated.

In order to check for possible anticipatory postural adjustment that might have taken place prior to the actual occurrence of disturbance, the lateral position of the baseline COP was examined. A three-way repeated ANOVA showed a tendency of left lean before right-oriented perturbations and vice versa ($F(1,9) = 8.895$, $p = .015$)($F(1,11) = 5.774$, $p = .035$). This tendency was more obvious with predictable direction of incoming disturbance in Experiment 1 ($F(1,9) = 13.146$, $p = .006$) with elderly participants.

Response time is a powerful index into the efficiency of the nervous system in processing information and responding to stimuli [24]. Under the influence of reflex/hierarchical model of motor control, response time of postural responses had been viewed for long as an index of

efficiency of the lower hierarchies of the nervous system and considered rather invariant. Nevertheless, previous research that manipulates predictability of disturbance onset has evidenced the involvement of cortical activities in postural responses, thus implying potential predictive contributions to the control of postural responses [1;13]. Dietz and colleges [13] used a participant-triggered paradigm, contrasted to the unpredictable condition of experimenter-triggered perturbation. Adkin et al. [2] adopted a paradigm with an auditory cueing immediately prior to experimenter-triggered perturbation. Both of the above studies, however, focused on measure of cortical responses and put no interests on behavioural measures such as response time.

This study is, to the authors' knowledge, the first one that looks into effects of temporal predictability of balance disturbance on behavioural measures. By identifying a regularly onset paradigm of a series of perturbations, the results revealed that when the neurologically normal participants were cued with timing of incoming disturbance, there was slower response onsets, comparing to the condition of temporally unpredictable perturbations. The above finding on effects of temporal predictability was generally not associated with anticipatory adjustment of postural lean.

Given temporal anticipation on postural response waveforms, why was a shorter response time not obtained? We thought this most likely due to heightened alertness with uncertain onset timing of forthcoming disturbance in our designed context. It has been shown that arousal level alters as a function of perceived postural threat [8;9]. Our study adopted very light perturbations, and all participants, who have relatively healthy status and balance ability, reported that they perceived the balance task rather easy. Therefore, participants' arousal level was generally low in our study, and the uncertainty of onset timing of forthcoming disturbance might relatively raise the level of arousal and resulted in shorter response time. We predicted that with increased threatening level of disturbance by recruiting disabled participants or by increasing perturbation amplitudes, the arousal level may become equal between conditions of predictable and unpredictable onset timing, and as a result, effects of temporal predictability on response time may be evidenced. Future studies should assess also the arousal level to validate the above hypothesis.

In conclusion, the study offers a novel regular paradigm for studying the effects of temporal predictability of disturbance on postural responses. By using this paradigm, we have been able to evidence the manipulability of postural response time in healthy elderly and young participants. Although the beneficial predictive effects on response time were not shown, we suggest future studies to examine the same issue with increased threatening magnitudes of disturbance to standing balance, or in a balance disabled population while also measuring arousal level.

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參、計畫成果自評

本研究計劃為計畫主持人之第一個計劃，低估了平衡干擾儀與相關設備軟體之完成所需之自行開發時間，因此在軟硬體開發完成後只完成了三個前置實驗，達成預期目標情況方面只有6成。執行之研究內容與原提計畫書相符程度高，主要目的與研究方法皆未大幅更

改。

未來研究成果之學術與臨床應用價值如下：平衡干擾儀與相關設備軟體之完成將可申請專利，探索運用預期性平衡控制之可能潛力之研究成果將可發表於動作控制之相關學術期刊，未來進一步運用上述潛力以發展中風病患訓練方法之研究成果將可發表於物理治療之相關學術期刊，並可逐漸推廣此新的治療觀念與方法於臨床工作。

本人於 2009 年 6 月 21-25 日出席於義大利波隆那舉辦之「第 19 屆姿勢與步態研究國際研討會」(the XIX conference of the international society for posture and gait research)，茲簡述此研討會如下。

1. 專題演講「Variability and coordination in posture and locomotion across the life-span」：Dr. Newell 講論研究中常用的變異性-例如標準差、標準誤。傳統研究中將變異性視爲誤差值，但新的趨勢則認爲變異性傳遞了動作控制的重要特性，不應該被忽略……。
2. 趣味辯論「Preferring preferred speed?」：Dr. Duysens 和 Dr. Bloem 分別擔任正反方，辯論病理步態研究中常用的舒適走路速度是否合理。正方提出使用速度爲共變因子爲可行的統計方法，反方則提出許多有趣的觀點，例如一項研究不應該有兩個以上操弄的因子、舒適走路速度真的存在嗎…⋯。
3. 論文口頭報告：分爲多項主題，其中 cognitive, attentional, and emotional influences 以及 learning, plasticity and compensation 爲本人最感興趣的部份。由報告內容可以看出關於注意力、學習等主題仍爲熱門的研究領域。
4. 論文海報展示：也是本人此次報告的方式，與會者與報告者有非常熱烈的討論，也刺激本人在將來投稿的寫作上很多的想法。