行政院國家科學委員會專題研究計畫 成果報告

閱譜之視知覺處理歷程：事件誘發電位研究
研究成果報告(精簡版)

計 畫 類 別 ：個別型
計 畫 編 號 ：NSC 99-2410-H-040-007-
執 行 期 間 ：99 年 08 月 01 日至 100 年 07 月 31 日
執 行 單 位 ：中山醫學大學心理學系（所）（臨床組）

計畫主持人：李宏鎰

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中 華 民 國 100 年 09 月 07 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

閱譜之視知覺處理歷程：事件誘發電位研究

The Visual Processing of Music Reading: An ERP study

計畫類別：■ 個別型計畫　□ 整合型計畫
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共同主持人：(無)
計畫參與人員：趙家嬅、王譽心、呂文潔、李逑富

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：中山醫學大學心理系

中　華　民　國　一百　年　九　月　五　日

閱譜之視知覺處理歷程：事件誘發電位研究

摘要

音樂訓練可以增強非音樂領域的認知能力，包括視空間能力。本研究的主要目的是探討音樂訓練會進成那些 ERP 成分會增強或消弱。我們使用電生理及行為測量的方法比較音樂系及非音樂系大學生處理單一音符的音高及節拍訊息時的表現。結果發現音樂訓練使得音樂班的學生在閱讀單音符時，可以誘發較大的 N1 波，此表示音樂班學生可以從視覺化的單音符中獲得音高的聲音意義。相對的，音樂班學生的 N2 振幅較小，此表示音樂班學生對單音符的音高位置判斷已經相當熟悉化，不需動用那麼多的視空間處理資源了。

關鍵詞：時長處理，音樂專長，音高處理，視空間注意力

The Visual Processing of Music Reading: An ERP study

Abstract

Musical training enhances a range of nonmusical cognitive functions, including visuospatial abilities. The aim of this study was to explore which ERP component was enhanced and reduced from training of music reading. We used both electrophysiological and behavioral methods to compare musicians and nonmusicians in the processing of pitch and duration in reading single musical notes. It was observed that in the early stage of note reading, the expertise effect emerged in the latency range of the N1 and N2. The N1 component was enhanced, by contrast, the N2 component was reduced in musicians. It is possible that musicians receive auditory meanings from visual music notations, and they did not necessary to spend more resources on executing spatial attention than nonmusicians.

KEYWORD: duration processing, musician, pitch processing, visuospatial attention

INTRODUCTION

Several studies have shown that the auditory cortex responds differently to sound in musicians then in nonmusicians, and this difference can also be enhanced through auditory training. For example, Event-related potentials (ERPs) have shown enhanced N1 responses at about 140 msec. after sound onset and enhanced P2 responses at about 180 msec. Moreover, the effect of expertise measured at the Cz electrode was larger than that at the T8 electrode, source localization analyses locate the generators of the activation to secondary auditory cortex and superior temporal gyrus (Shahin, Bosnyak, Trainor, & Roberts, 2003). Furthermore, it has also been shown that the amplitude of the P2 component increases when nonmusicians are trained to make an auditory discrimination (Tremblay, Kraus, McGee, Ponton, & Otis, 2001). Trainor, Shahin, and Roberts (2003) compared both adult and child musicians and nonmusicians who listened to the sounds of violin, piano or pure tones. The results showed that the amplitude of P2 component was higher in both adult and child musicians than in nonmusicians, and this component could be enhanced through auditory training in adult nonmusicians. Thus, the P2 component is particularly neuroplastic. Besides, the N1 component was enhanced in children who had musical experience other than the P2 component.

The effects of musical expertise or training on sound representations in the auditory cortex have been found. However, these effects elicited from the stimuli in the auditory modality, the originality of this research is to investigate the expertise effects in the visual modality. Some brain imagery studies had shown the possibility that visual presentation elicited the same expertise effect as sound presentation. Halpern and Zatorre(1999) found that when musicians had to imagine the continuation of a tune cued by its first few notes, the right auditory association cortex were active. Schürmann, Raij, Fujiki, and Hari(2002) found that when musicians had to imagine the sound of a single note presented visually, the left auditory association areas were active. Wong and Gauthier (2010) investigated expertise effects during visual judgments with musical notation with functional Magnetic Resonance Imaging (fMRI) and found that a distributed multimodal network of areas was recruited for musical notes for music-reading experts. This network included visual, primary and associative auditory, somatosensory, audiovisual, premotor, parietal, and frontal areas. The activity in primary and associative auditory areas suggests that music-reading experts get the auditory meaning of visual musical notes easier than novices. Furthermore, Schön and Besson (2005) found that musicians can develop expectancies for specific stable or unstable auditory events based on the visual score alone, and that seems to influence auditory processing as early as 100 msec. (N1). Accordingly, we predicted the amplitude of N1 or P2 components were larger in musicians compared to nonmusicians in reading musical notation.

In addition, in standard Western musical notation, the staff is a set of five horizontal lines and four spaces, each of which represents a different musical pitch. The pitch dimension is expressed by the specific position of the note head on the five-line staff, a higher position indicating a higher pitch. The temporal dimension of a single note is expressed by the form of the note, depending on the flag, the stem, the head, and the dot after the note. Thus, in music notation, pitch and temporal information are coded separately, distinguished by different attributes, and used different cognitive capabilities. Pitch processing relies on visual spatial ability, whereas rhythm processing relies on object recognition (Bengtsson, & Ullén, 2006). Pitch processing results in a learning-related change in superior parietal cortex, whereas rhythm processing results in a learning-related change in temporal cortex (Stewart, 2008). In this study, the expertise effects in the pitch and duration processing were also separately investigated.

Most studies have shown that parietal areas were recruited because of the visuospatial nature of musical notation (e.g. Stewart et al., 2003; Schön, Anton, Roth, & Besson, 2002; Sergent, Zuck, Terriah, & MacDonald, 1992; Wong & Gauthier, 2010). However, some other studies have found that lower activity in parietal regions in pianists (Bengtsson, & Ullén, 2006; Krings et al., 2000), that is most likely that the musicians exhibit high-level piano skills which results in a high degree of automatization (Bengtsson, & Ullén, 2006). Thus, it is interesting that whether some ERP components related visuospatial processing in the parietal cortex can also be reduced in musicians. We used the characteristic of ERPs with high temporal resolution to explore this issue, and predicted that N2 at the Pz electrode elicited by pitch processing was not obvious for musicians than nonmusicians, because musicians processed the pitch dimension of a note more automatic than nonmusicians, and the pattern of enhancement of N2 components has been interpreted in terms of executing visuospatial attentional processing (e.g. Lee & Wang, 2011; Rosazza, Cai, Minati, Paulignan, & Nazir, 2009). In contrast, it was not predicted the N2 components to be observed during processing of duration that relied on object recognition for all.

METHOD

Participants

Participants included 12 musicians (1 man, mean age = 20.9, SD = 1.5) and 24 nonmusicians (7 men, mean age = 21.2, SD = 1.2). Experts had received at least 8 years of formal musical training (M = 14.7 yr., SD = 3.0) and had a high self-rating score on music-reading ability [M = 2.83, SD = 0.39 in a 4-point scale, ranging from 0 (pretty difficult to read music) to 3 (pretty easy to read music)]. Nonmusicians had never received any formal music training and had a low self-rating score (M = 1.25, SD = 1.12). Nonmusicians majored in subjects other than music, but they had acquired basic knowledge of Western music notation by taking music courses during the period from elementary school to senior high school in Taiwan. All participants were right-handed except one left-handed musician, and all reported normal or corrected-to-normal vision and no history of neurological disorders.

Stimuli

Visual stimuli were presented at the center of a computer screen (17-in. NEC SVGA color monitor). The experiment was divided into pitch and duration tasks with different targets. In each trial of both tasks, a fixation cross appeared for 400 msec., followed by a blank screen for 200 msec. (to collect baseline data for analyzing ERPs) and a target for 1,000 msec. The target of the pitch task was a note with different vertical positions that varied from the space below the staff to the third line, but the time value of the note was always a quarter note, which forced participants to judge pitch only. The target of the duration task was a note with different time values (eighth note, quarter note, dotted quarter note, half note, dotted half note, or whole note), but the position of the note was fixed at the third line on the staff, so participants could judge time value only. The Sol-Fa name and time value of a target note were defined by C major and 4/4 time, respectively, because this is the simplest context and suits novices.

After the presentation of a target, the screen was blank for 1,000 msec. before a response display appeared for 1000 msec. The response display comprised a solmization syllable or a note value written in Chinese characters, as used in the study of Lee and Wang (2010). At this point, the participants had to judge if the target and response display were congruous, i.e., judge if the pitch of target and the solmization syllable designated by the response display were congruous, or if the time value of the target note and the note value designated by the response display were congruous. Participants were required to press the keyboard to indicate congruity (the “Z” key) or incongruity (“M”). The association between responses and response keys was counterbalanced across participants. After responding, the screen went blank for 1,500 msec. Each task had 180 trials.

Procedures

Each participant was seated 50 cm from the computer monitor. All participants were instructed to respond as quickly as possible, and were given 25 practice trials for each task to be familiar with the task before the onset of the formal experiment. All participants performed the pitch and rhythm tasks successively, and the order was counterbalanced across participants.

Data Acquisition and Analysis

E-prime (Psychology Software Tools, Pittsburgh, PA) was used to control experimental procedure and to record the behavioral data. EEG activity was recorded from 32 scalp locations using a Neuroscan Q-cap AgCl-32 electrode cap. The horizontal electrooculogram (hEOG) was recorded from the corners of both eyes, and the vertical electrooculogram (vEOG) from the upper and lower positions of the left eye. All recording sites were referenced to linked mastoids. The ground electrode was located at the linkage position between the cap and the forehead of the participant. Electric impedances were kept below 5 kΩ. Both EEG and EOG were obtained through SYNAMPS amplifiers (Neuroscan, Inc.) after ocular artifact reduction, baseline correction (the baseline was set at the level before the presence of target stimulus), artifact rejection (trials with the brain waves that had amplitudes not within −75 to 75μV), and filtering (0.1 to 30 Hz band pass, 12dB/oct), the evoked potentials of each task were averaged across epochs (the interval of an epoch was 200 msec. before the presence of each target and 500 msec. after its presence). The average acceptance rate was 89.74% (SD=10.11). ERP data were analyzed by computing the mean amplitude in selected latency windows.

RESULTS

Table 1 shows the behavioral data. The data were analyzed by two-way (Task × Group) mixed design ANOVA. Reaction times were not significantly faster for experts than for novices ($F_{1,34}=0.59$, $p=.45$; $\eta^2=0.02$), not significantly faster for pitch task than for duration task

($F_{1,34}$=0.61, *p*=.44; η^2 =0.02), and there was no significant Task × Group interaction ($F_{1,34}$=0.76, *p*=.39; η^2 =0.02). However, correct percentages were significantly higher for experts than for novices ($F_{1,34}$=4.66, *p*= < .05; η^2 =0.12), but not significantly lower for pitch task than for duration task ($F_{1,34}$=0.58, *p*= .45; η^2 =0.02), and there was no significant Task × Group interaction ($F_{1,34}$=1.13, *p*=.30; η^2 =0.03). As expected, novices made more errors than experts in both pitch and duration tasks.

insert Table 1 about here

Group-averaged ERPs are shown in Fig.1, separately for musicians and nonmusicians. According to the previous research results (Shahin et al., 2003; Trainor et al., 2003; Tremblay et al., 2001), the effect of expertise was expected to reveal N1 and P2 with larger amplitude for musicians than for nonmusicians at the Cz electrode than the other electrodes.

In the pitch task, at the Cz electrode, student *t* tests showed that the N1 amplitude (150–200 msec.) was greater for musicians than for nonmusicians (t_{20}= -2.90; p < .01; Cohen's *d* = -1.30). For the P2 amplitude (200–290 msec.), it were not significantly different between musicians and nonmusicians (t_{17}= 0.09; *p* = .93; Cohen's *d* = 0.04). Constrastly, at the Pz electrode, it was not significantly different between musicians and nonmusicians for the N1 and P2 amplitudes (t_{23}= -1.27 ; *p* = .22; Cohen's *d* = -0.53; t_{22}= 1.35; *p* = .19; Cohen's *d* = 0.58). In the duration task, at the Cz electrode, it showed that the N1 amplitude was greater for musicians than for nonmusicians (t_{15}= -2.94; p < .05; Cohen's *d* = -1.52). For the P2 amplitude (200–290 msec.), it were not significantly different between musicians and nonmusicians (t_{18}= -0.40; *p* = .69; Cohen's *d* = -0.19). Similarly, at the Pz electrode, it was not significantly different between musicians and nonmusicians for the N1 and P2 amplitudes (t_{23}= -1.75 ; *p* = .09; Cohen's *d* = -0.73; t_{22}= 0.46; *p* = .65; Cohen's *d* = 0.20).

In addition, according to the previous research results (Bengtsson & Ullén, 2006; Lee & Wang, 2011), the effect of expertise was expected to reveal N2 with larger amplitude for musicians than for nonmusicians at the Pz electrode than the other electrodes. In the pitch task, at the Cz electrode, for the N2 amplitude (290-350 msec.), it were not significantly different between musicians and nonmusicians (t_{18}= 1.60; *p* = .13; Cohen's *d* = 0.75). Constrastly, at the Pz electrode, there was a marginally significant difference between musicians and nonmusicians for the N1 and P2 amplitudes (t_{17}= 1.99; *p* = .06; Cohen's *d* = 0.97). In the duration task, at the Cz and Pz electrodes, for the N2 amplitude, it were not significantly different between musicians and nonmusicians (t_{18}= 0.35; *p* = .73; Cohen's *d* = 0.16; t_{17}= 0.55 ; *p* = .60; Cohen's *d* = 0.27).

insert Fig. 1 about here

DISCUSSION

This research compared musicians and nonmusicians in two notation decision task included pitch and duration tasks. The behavioral data showed that the correct percentage of both tasks showed the difference of musical notation reading ability between musicians and nonmusicians, but not reaction time.

The ERPs showed an effect of expertise, too. In the early stage of note reading, as expected, expertise effect differed as a function of early ERP components and electrode positions. The amplitude of N1 component was higher among musicians than among nonmusicians and that seemed higher over Cz than over T3 and T4. This result is consistent with previous research foundings (Shahin et al., 2003; Trainor et al., 2003). This is also in line with the founding of Schön and Besson (2005) that there is an early effect of visual information on auditory processing that of top-down influences on the N1. It could support the hypothesis that visual musical notes elicited the same expertise effect as their sound presentation. In other words, with expertise, the auditory meaning of music notations is easily accessed from visual presentation alone (Wong & Gauthier, 2010). In addition, in the present study, a more interesting thing is that these effects of expertise could be observed in both pitch and duration tasks, thus not only the auditory meaning of pitch of a note could be elicited alone by the specific position of the note head, but also the auditory meaning of duration of a note could be elicited by the form of the note. However, the P2 component was not significantly enhanced in musicians in this study. It may be the case that P2 enhancement existed only in the auditory modality. In the previous studies, the P2 component was often enhanced in nonmusicians who received auditory training (Atienza, Cantero, & Dominguez-Marin, 2002; Trainor et al., 2003; Tremblay et al., 2001), by contrast, the N1 was not amplified by all of laboratory training in the above-mentioned EEG studies.

The amplitude of N2 over Pz in musicians was significantly smaller compared with nonmusicians and this result was found just only in the pitch task. In other words, the activities in the parietal cortex were low in experts compared to the novice group. This might be possible due to experts exhibited automatized note-naming skill, thus they did not necessary to spend more resources on executing spatial attention than novices. Because the involvement of the parietal lobe in note reading could be subserving a serial mechanism of visual attention, that is required to shift attention from one line or space to another on the staff (Lee & Wang, 2011). Similar results could be found in brain imaging studies of pianists. Bengtsson and Ullén (2006) found that when pianists were required to strike the piano keys, which needed to use the spatial processing, the low activity was seen in parietal cortex. They stated that this might be due to the fact that the pianists play piano with a high degree of automatization. Besides, in superior parietal cortex, reduced activation has been reported for pianists in comparison with nonpianists during the performance of a series of sequential finger-to-thumb oppositions (Krings et al., 2000).

We concluded that the N1 evoked by visual musical notes was enhanced in the pitch and duration tasks, by contrast, the N2 was reduced in musicians compared with nonmusicians who had not received formal music training in the pitch task.

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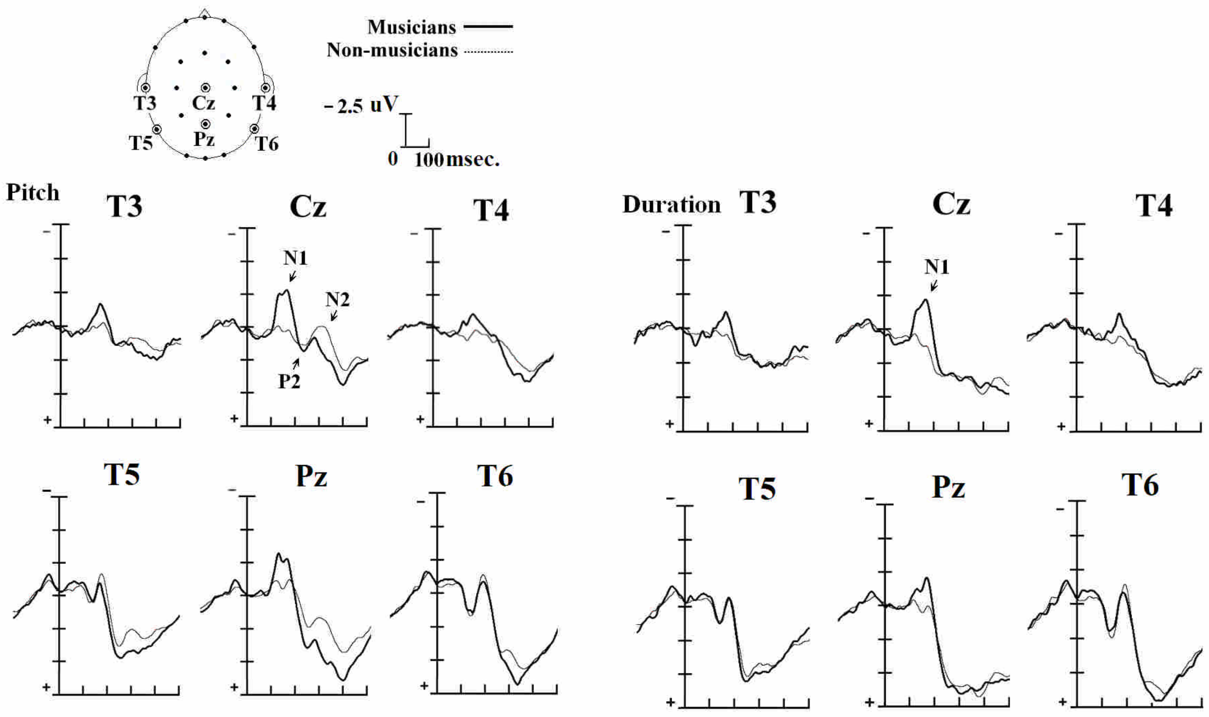
TABLE 1

MEANS AND STANDARD DEVIATIONS OF REACTION TIMES (RT) AND CORRECT PERCENTAGES OF PITCH AND DURATION TASKS FOR MUSICIANS AND NONMUSICIANS

Task / Group	RT (msec.)		% Correct	
	Pitch	Duration	Pitch	Duration
Novice (n=16)	522.1(94.1)	502.2(91.5)	89.9(11.0)	89.7(9.3)
Expert (n=12)	490.6(64.1)	491.8(58.9)	95.6(5.3)	97.0(2.6)

Fig. 1. Event-related potential waveforms recorded in pitch experiment (a) and duration experiment (b) at T3, Cz, T4, T5, Pz and T6 electrode sites. The vertical line at zero stands for the onset of the target. The musician is shown in bold, and the nonmusician is shown in dashed line.

a) b)



計畫成果自評

一、研究內容與原計畫相符程度

本研究內容完全依照原計畫進行，然而考量在一般大學生中所篩選出的閱譜困難者，可能只是閱譜能力較弱者，而不是所定義的閱譜困難者或是閱譜障礙者。因此，在撰寫報

告及發表時，合併統稱為一般組，進一步將之與音樂班大學生做比較。

二、研究成果與應用價值

本研究主要發現音樂訓練使得音樂班的學生在閱讀單音符時，可以誘發較大的 N1 波，此表示音樂班學生可以從視覺化的單音符中獲得音高的聲音意義。相對的，音樂班學生的 N2 振幅較小，此表示音樂班學生對單音符的音高位置判斷已經相當熟悉化，不需動用那麼多的視空間處理資源了。日後，N1 與 N2 可作為音樂訓練的成果指標，甚至判斷閱譜能力強弱的指標。

三、本研究部分成果已經發表，部分已經投稿出去，適合在學術期刊上發表

本研究的主要目的是探討閱譜歷程與視覺雙路徑假設之關係，及一般生與音樂班大學生之閱譜歷程。針對一般大學生的閱譜歷程與視覺雙路徑假設之關係已經發表(註一)，另外關於一般科系大學生與音樂班大學生之閱譜歷程比較的部分則已經投稿出去，正在審查中，內容如本計劃成果所示。

註一: Lee, H. -Y.* & Wang, Y. -S. (2011). VISUAL PROCESSING OF MUSIC NOTATION: A STUDY ON EVENT-RELATED POTENTIALS. Perceptual and Motor Skill, 112(2), 525-535. (NSC 99-2410-H-040-007) (SSCI)

國科會補助計畫衍生研發成果推廣資料表

日期:2011/09/06

國科會補助計畫	計畫名稱: 閱譜之視知覺處理歷程：事件誘發電位研究
	計畫主持人: 李宏鎰
	計畫編號: 99-2410-H-040-007- 學門領域: 教育及教學心理學

無研發成果推廣資料

99 年度專題研究計畫研究成果彙整表

計畫主持人：李宏鎰	計畫編號：99-2410-H-040-007-
計畫名稱：閱譜之視知覺處理歷程：事件誘發電位研究	

成果項目			量化：實際已達成數（被接受或已發表）	量化：預期總達成數(含實際已達成數)	量化：本計畫實際貢獻百分比	單位	備註（質化說明：如數個計畫共同成果、成果列為該期刊之封面故事...等）
國內	論文著作	期刊論文	0	0	100%	篇	
		研究報告/技術報告	1	1	100%		
		研討會論文	2	2	100%		
		專書	0	0	100%		
	專利	申請中件數	0	0	100%	件	
		已獲得件數	0	0	100%		
	技術移轉	件數	0	0	100%	件	
		權利金	0	0	100%	千元	
	參與計畫人力（本國籍）	碩士生	0	0	100%	人次	
		博士生	0	0	100%		
		博士後研究員	0	0	100%		
		專任助理	0	0	100%		
國外	論文著作	期刊論文	1	2	100%	篇	
		研究報告/技術報告	0	0	100%		
		研討會論文	1	1	100%		
		專書	0	0	100%	章/本	
	專利	申請中件數	0	0	100%	件	
		已獲得件數	0	0	100%		
	技術移轉	件數	0	0	100%	件	
		權利金	0	0	100%	千元	
	參與計畫人力（外國籍）	碩士生	3	3	100%	人次	
		博士生	0	0	100%		
		博士後研究員	0	0	100%		
		專任助理	0	0	100%		

其他成果 (無法以量化表達之成果如辦理學術活動、獲得獎項、重要國際合作、研究成果國際影響力及其他協助產業技術發展之具體效益事項等，請以文字敘述填列。)	無

	成果項目	量化	名稱或內容性質簡述
科教處計畫加填項目	測驗工具(含質性與量性)	0	
	課程/模組	0	
	電腦及網路系統或工具	0	
	教材	0	
	舉辦之活動/競賽	0	
	研討會/工作坊	0	
	電子報、網站	0	
	計畫成果推廣之參與（閱聽）人數	0	

國科會補助專題研究計畫成果報告自評表

請就研究內容與原計畫相符程度、達成預期目標情況、研究成果之學術或應用價值（簡要敘述成果所代表之意義、價值、影響或進一步發展之可能性）、是否適合在學術期刊發表或申請專利、主要發現或其他有關價值等，作一綜合評估。

1. 請就研究內容與原計畫相符程度、達成預期目標情況作一綜合評估

■達成目標

□未達成目標（請說明，以 100 字為限）

□實驗失敗

□因故實驗中斷

□其他原因

說明：

2. 研究成果在學術期刊發表或申請專利等情形：

論文：□已發表 ■未發表之文稿 □撰寫中 □無

專利：□已獲得 □申請中 ■無

技轉：□已技轉 □洽談中 ■無

其他：（以 100 字為限）

3. 請依學術成就、技術創新、社會影響等方面，評估研究成果之學術或應用價值（簡要敘述成果所代表之意義、價值、影響或進一步發展之可能性）（以 500 字為限）