Investigation of Road-crossing Safety Before and After Training for patient with Parkinson's disease

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In our previous study [Predictors of road crossing safety in pedestrians with Parkinson’s disease, Accident Analysis and Prevention 51, 202-207, 2013], we have found that patient with PD had decreased ability to cross the road as compared to age/gender matched control subjects. Hence, this research proposed training program to enhance the safety of crossing road. Discussing the situation where the vehicle is approaching, investigate the before and after training difference in decision making behaviour of road crossing. Sixty PD patients without neurological disease were recruited to participate in this study. The results of this study showed that the different methods of training display different results on Parkinson’s patients, they have the tendency to perform better one month after the training. The effects of training programs will be provided for further safety management and design concepts to improve the lives of this disease group.

Keywords: Training, Parkinson’s disease, Road crossing, Pedestrians

1. Introduction

The human lifespan has been increasing over the years due to the economic development and improvements in medicine. Aging population has emerged as a global trend. According to the standard established by the United Nations, when 7% of the population exceeds 65 years old, a county is considered an “Aging Society”. Statistics from the Department of Household Registration, M.O.I. indicates that Taiwan has become an aged society since 1993. The proportion of people aged 65 or older increased from 7.10% in 1993, to 10.89% in 2011, with the rate of growth of 3.79%. The aging population index has moved from 28.24% to 69% and displays a growing trend by the year. Hence, issues with regards to aging population have received greater attention (Department of Household Registration of MOI, 2012). With the increase of the elderly population, the rage of older and aging associated disease (such as PD, lower level of movement and cognitive ability relative to other elderly adults) road user has increased as well. Therefore, the effect on the traffic safety environment and impact of the abovementioned combination requires further analysis.

The health related disease of the elderly in Taiwan has transformed from acute to chronic, the most commonly observed neurodegenerative type of diseases are dementia and Parkinson’s disease (PD). The research of Olmsted County (Mayo Clinic) points out that the percentage of PD in men is 2% and 1.3% for women (Elbaz et al., 2002). There is around 0.5 to 1% of those between the age of 65 and 69 suffers from PD. For persons above the age of 80, the rate of PD increases to 1 ~ 3% (Tanner and Goldman, 1996).

The primary issue with the PD is movement disability and deterioration of the cognitive and then affecting the work and daily life of patients, hence the possibility of making erroneous judgment when crossing the road. Due to the fact that the deterioration of the functions caused by Parkinson’s disease happens gradually, which made it difficult to be certain about the period of the deterioration of functions. Such made it difficult for the patient to judge the change in the level in deterioration, causing danger to the patient and other road users. Yet, the road design has not considered the issue of neurodegenerative disease of the elderly adult, related researches has not focused on the effect of Parkinson’s disease on traffic safety. With the increase in the rate of Parkinson’s disease, such points out the urgency and importance of the problem.

As for the literature of road-crossing ability of PD patients there are currently no researchers involved in related study in Taiwan. Living in the era of the aging population with the gradual increase in the number of...
patients of PD, we hope that this study can initiate the emphasized awareness of the traffic safety of the PD patients. In this study, designing the training method in order to compare before and after training is improved to the participant.

2. Literature Review

2.1 Parkinson’s Disease

Parkinson’s disease (PD) is one of the most common neurodegenerative diseases, which incidence increases as age more than 50 years. According to the study of Olmsted county conducted by Mayo Clinic, the lifetime risk of PD is around 2% for males and 1.3% for females (Elbaz et al., 2002). There is around 0.5 to 1% of persons between the age of 65 and 69 suffers from PD and. the risk of suffering the disease increases to 1-3% over the age of 80 years (Tanner and Goldman, 1996). Based on the neuroepidemiological study conducted in Ilan County, it affects approximately 25,000-30,000 individuals in Taiwan (Chen et al., 2001). Therefore, as worldwide life expectancy has increased, the burden of chronic neurodegenerative diseases, such as PD, has grown exponentially. One recent study has estimated that the number of individuals over age 50 with PD in 2005 was between 4.1 and 4.6 million and project that the number will more than double by 2030 to between 8.7 and 9.3 million (Dorsey et al., 2007).

2.2 Related Research on Road Crossing Decisions

Past research have pointed out that with the age-related changes leads to the change in the road-crossing behaviour. Some examples include decreased walking speed, lag in decision making, decline in cognitive ability and difficulty in choosing safety gaps, which all lead to the inability to assess safety barrier (Holland, 2001; Lobjois and Cavallo, 2007, 2009; Oxley et al., 2005, 2006). The pedestrian should know the traffic environment, vehicle direction and certainty of enough time to cross prior to the arrival of the vehicle before crossing the road. There is also a need for the ability to maintain awareness until the process of road-crossing is complete. Therefore, these are some of the abilities required to safely cross the road: (1) Confirm the difference in distance between the vehicles (time gap); (2) How much time required to safely crossing the road (for example: walking speed and acceleration ability). In principle, safe crossing occurs when time available to cross is greater than the actual crossing time.

In many countries, the rate of pedestrians being collided is around 12% to 20% (ATSB, 2002; Hakkert et al., 2002; NHTSA, 2001). According to the study conducted by Guerrier and Jolibois (1998) they indicated that 70% of the pedestrian-vehicle conflicts are inflicted by the pedestrian. Furthermore, pedestrian collision accidents increase with higher vehicle speed and higher flow of traffic (Roberts et al., 1995).

The decision to cross the road is often affected by various factors. Some of these factors include external environment (Yagil, 2000; Yang et al., 2006; Oxley et al., 1997), traffic signals (Keegan and O’ Mahony, 2003; Hatfield et al., 2007), and road width (Tarawneh, 2001). Yagil (2000) utilized the survey method to investigate what are the factors that affect pedestrians crossing the road. The result shows that the pedestrians are affected by external factors, such as vehicle flow, behavior of other pedestrians, causing variations in road-crossing behavior. Yang et al. (2006) have found similar results in their research, pedestrians have high rate of being affected by others (around 69%). Further indicates that external environment affect the road-crossing decision making of the pedestrians, for example, volume of traffic flow, other pedestrians and the presence of police officers. Observations of Oxley et al. (1997) have found that complex traffic situations can affect the road crossing decision behavior of the elderly.

2.3 Related Research on Road Crossing Training

The high rate of accident in crossing the road is astounding. Therefore, various training methods are adopted to improve the safety and techniques in crossing the road. In the past, these training methods have been proven to effectively improve the road crossing knowledge and safety of the children and the elderly. No matter it be the real or simulated environment, the training programs can effectively improve the road crossing technique of the pedestrians (Novak, 2009). For example, the judgment of crossing the road (Thomson et al., 2005), crossing an intersection (Rothengatter, 1981 · 1984), distinguishing dangerous
factors on the road (Thomson et al., 1992; Thomson and Whelan, 1997), and improve awareness (Tolmie et al., 2002). There are various training methods brought forward by past research, the most often seen are virtual environment training, computer game training, film tutorial, and normal teaching of the knowledge.

3. Methodology

3.1 Participants

There are two groups in this study (PD patients and normal elderly) with the help of related doctors of the National Taiwan University Hospital of Yunlin Branch. Forty-eight participants were chosen from each group to participate in this experiment. We are able to filter out the suitable PD participants. The criteria for the participant include: (1) PD patient (stage I – III) or healthy volunteer that fits the age and gender matching. (2) Aged between 55 and 85 years (3) Have signed the agreement.

3.2 Simulated Road Crossing Experiment

All participants completed a pre-test evaluation to examine their baseline walking behaviors. Walking speed was measured on a 10-meter road under normal pace and fast pace conditions. This experiment uses 3d max 2011 for construction of the scenery and uses FLASH edit timer, finally, an ASUS laptop computer is used to execute this experiment. The road format is a straight single lane road, a road junction without traffic lights, with lane width of 3.5 meters as displayed in Figure 1. Since vehicles in Taiwan are required to keep to the right hand side of the road, so the camera footage only consider vehicles approaching from the left. The traffic condition includes two vehicles approaching the test subject at the same velocity. At the beginning of each scene, the vehicle was 2 s away from the pedestrian. During the experiment, the image is projected on to the screen with image size of 1m x 1.5m.

3.3 Experimental Design

Experiment is divided into two stages, with stage 1 being road crossing experiment, and section 2 being road crossing safety training. The experiment is 2 (road user: normal elderly and PD patient; between-subjects) x 2 (vehicle size: motorcycle and vehicle; within-subjects) x 2 (speed: 40km/hr vs. 70km/hr; within-subjects) x 4 (time gap: 2s, 4s, 6s, and 8s; within-subjects) x 3 (Training: before training vs. post training vs. one month after training, within-subjects). There is a total of 48 tests in the experiment combination, every test subject is required to execute complete experiment combination for two times, with a total of 96 times.
The main outcome variables were crossing time (CT), remaining time (RT) and safety margin (SM). The CT was the time taken by the subjects to cross the 3.5-m-wide road. The CT was measured at the normal walking pace and the fastest pace of each individual; RT (the time period remains for pedestrian safely crossing-road) which can be obtained by (time gap – the time of participant can safely crossing-road with his walking pace); The SM was the time difference between the RT and mean CT (i.e., average of the CTs at the normal pace and fastest possible pace). When the RT was less than the mean CT, the SM was negative, meaning that it was impossible to cross the road safely. In contrast, the SM had to be positive for the pedestrian to cross the road safely. The mean SM was calculated for each participant from each trial of an individual traffic scene.

3.4 Training

Road-crossing safety training was divided into two major parts: Part 1 is the normalized road-crossing knowledge and the important items to know to cross the road including width of the road, finding a safe location, road right regulations and the road-crossing formula. Firstly, conduct road width assessment: the test subject is asked to observe the road width (3.5 meters and 10 meters), followed by asking the subject to conduct psychological walking behaviour. Which involved no physical movement of the subject but perform the walking in the mind. When the subjects begin the psychological walk the “Start” button is also pressed down, and press the “End” button when the subject reaches the end of the walk. The difference between the actual walk time and the estimated time is less than 10%. Next, PowerPoint tutorial is provided, including finding the safe location, use of road right regulation and formula for road-crossing. This stage of training takes around 20 minutes.

The second part is the decision ability training. Training of safety margin (Dommes et al., 2012): safety margin is informed after every road crossing attempt. If the safety margin is negative, then the pedestrian would not be able to cross the road. During the training process, the subject is asked to keep more than 1.5 second of safety margin(Simpson et al., 2003). If the safety margin falls below the 1.5 second threshold, the subject is requested to cross the road again until the subject can cross the road with accuracy and the training should end. This stage of the training takes around 10 minutes.

3.5 Procedures

The participants gave their consent for this study and were given information about the purpose of this experiment and the tasks they were about to perform. Firstly, through the training task the participant is able to understand the content of the task and procedure. Until the participant fully understand the experiment, and then enter the formal practice 4-10 times. Before the real experiment, examination of vision and color blindness is conducted, ensuring that every test subject does not have color blindness and a corrected vision of 0.5 and above. After vision examination, every subjects were asked to perform walking speed test, the subject has to walk in a fast pace and normal pace for 10 meters. The experiment personnel then records the time for fast pace and normal pace by a stopwatch. After the completion of the above task, the subject is required to take a 5 minute rest before undergoing the formal experiment in order to prevent fatigue.

Road-crossing experiment is divided into three stages. Stage one is before training data, stage two is the data gathered post training, and stage 3 being the data gathered one month after training. The description of the three stages is as follows.

Stage one is before training: the virtual reality scenery of the experiment is built with a two lane road environment (see Figure 1). The driver stands in front of the projector screen, with two vehicles approaching from the left hand side, the time gap of the two vehicles can be between 2 to 10 seconds (in 2 second increments). The driver has to wait until the first vehicle to pass the zebra crossing, then judge whether the gap between the first and second vehicle is suitable for passing. At the instant when the subjects believe that it is safe to cross the road the “Pass” button is pressed. At this instant, the experiment personnel will record the start to stop time of the footage. All test subjects are required to pass 80 times of the test (by random order) to be considered passing the entire phase of the experiment. At the end of every test, the experiment personnel will inquire about the degree of risk for crossing the road. The entire experiment takes around 30 minutes.
The second stage is post training test. Before the training, this research collects the result in advance the first attempt for road crossing and collecting post training.

Stage three is the result of one month after training. We track back the subjects and conduct the road crossing experiment once more. This is to explore can training be utilized to improve the road crossing safety of the pedestrians, or even prolong the performance for a longer period of time.

4. Results
4.1 Effects of training modality

Training of safety margin for Parkinson’s patient group

Table 1 is the summaries of ANOVA tables on success rate for training of safety margin in PD group. The ANOVA shows that the vehicle speeds, type of vehicle, time gap, and training condition have statistically significant effects on street-crossing success rates. The post-hoc analysis reveals that the bike has significantly lower street-crossing success rates than vehicle. The normal control group at 4 second time gap has the lowest success rates, followed by 6 second, 2 second and 8 second. The success rate for vehicle speed at 70 km/hr is lower than the vehicle speed at 40 km/hr. The Parkinson’s patient's performance is significantly better post training than before training and one month after training.

Two-way interactions between training x vehicle speed was significantly different in street-crossing success rate. At vehicle speed of 40 km/hr, no significant difference is observed in the street-crossing success rate between the different training groups; In the vehicle speed of 70 km/hr, the immediate after training has the highest street-crossing success rate than one month after training and before training.

Two-way interactions between time gap x training was significantly different in the success rate of street-crossing. In the 2 second time gap, the success rate street-crossing is significantly lower before training than post training and one month after training.

Two-way interactions between time gap x vehicle type was significantly different in street-crossing success rate. For the vehicle type, the 2 second, and 8 second time gap in road crossing success rate are significantly higher than the 4 second and 6 second time gap (P<0.001). For the bike type, the 2 second and 4 second time gap in road crossing success rate are significantly lower than the 6 second and 8 second time gap (P<0.001). In the 2 second, 4 second and 6 second time gap, the road crossing success rate is significantly higher in vehicle than in bike type (P<0.001).

Table 1. Average success rate(s) for the different training groups under different vehicle speed, time gap, and vehicle type on training of safety margin modality

<table>
<thead>
<tr>
<th>Variable</th>
<th>Before training (%)</th>
<th>Post training (%)</th>
<th>One month after training (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vehicle</td>
<td>40km/hr</td>
<td>84.1</td>
<td>85.9</td>
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<tr>
<td>speed</td>
<td>70km/hr</td>
<td>67.5</td>
<td>80.9</td>
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<tr>
<td>Time</td>
<td>2s</td>
<td>83.8</td>
<td>93.1</td>
</tr>
<tr>
<td>gap</td>
<td>4s</td>
<td>51.9</td>
<td>63.1</td>
</tr>
<tr>
<td></td>
<td>6s</td>
<td>68.1</td>
<td>78.1</td>
</tr>
<tr>
<td></td>
<td>8s</td>
<td>99.4</td>
<td>99.4</td>
</tr>
<tr>
<td>Vehicle</td>
<td>Vehicle</td>
<td>82.8</td>
<td>92.5</td>
</tr>
<tr>
<td>type</td>
<td>motor</td>
<td>68.8</td>
<td>74.4</td>
</tr>
</tbody>
</table>

Training of safety margin for the normal control group

Table 2 is the summaries of ANOVA tables on success rate for training of safety margin in NC group. The ANOVA shows that the vehicle speeds, type of vehicle, time gap, and training condition have statistically significant effects on street-crossing success rates. The post-hoc analysis reveals that the bike has significantly lower street-crossing success rates than vehicle. The normal control group at 4 second time gap has the lowest success rates, followed by 2 second, 6 second and 8 second. The success rate at the vehicle
speed of 70 km/hr is lower than the vehicle speed at 40 km/hr. The normal control group’s performance is significantly higher post training than before training.

Two-way interactions between time gap x vehicle type are significantly different in street-crossing success rate. For the vehicle type, the 2 second, 6 second and 8 second time gap in road crossing success rate are significantly higher than the 4 second time gap. For the bike type, the 4 second time gap in road crossing success rate is significantly lower, followed by the 2 second, 6 second and 8 second time gap. In the 2 second, 4 second and 6 second time gap, the road crossing success rate are significantly higher in vehicle than in bike type.

Table 2. Average success rate(s) for the different training groups under different vehicle speed, time gap, and vehicle type on training of safety margin modality

<table>
<thead>
<tr>
<th>Variable</th>
<th>Before training (%)</th>
<th>Post training (%)</th>
<th>One month after training (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vehicle 40km/hr</td>
<td>89.1</td>
<td>93.4</td>
<td>93.4</td>
</tr>
<tr>
<td>speed 70km/hr</td>
<td>82.8</td>
<td>91.6</td>
<td>86.9</td>
</tr>
<tr>
<td>Time 2s</td>
<td>81.3</td>
<td>92.5</td>
<td>88.1</td>
</tr>
<tr>
<td>gap 4s</td>
<td>65.0</td>
<td>78.8</td>
<td>72.5</td>
</tr>
<tr>
<td>6s</td>
<td>98.8</td>
<td>98.8</td>
<td>100</td>
</tr>
<tr>
<td>8s</td>
<td>98.8</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Vehicle type</td>
<td>Vehicle</td>
<td>94.1</td>
<td>98.1</td>
</tr>
<tr>
<td></td>
<td>motor</td>
<td>77.8</td>
<td>86.9</td>
</tr>
</tbody>
</table>

5. Discussion

Pedestrians with PD made risky crossing decision (indicated by negative safety margin) more often than matched normal elder. PD patients also had significant lower road crossing success rate, indicating they might not be aware of their declining cognitive abilities and motor ability in performing this road crossing decision and thus increasing the danger possibilities.

Given that factors of traffic environment also contribute to road safety, we findings that fast coming motor vehicle speed (70 km/hr > 40 km/hr), decreased time gap between two vehicle (4sec > 6sec = 2sec >8sec) and bike type increased risk of unsafe crossing road behaviors in both PD and control subjects. Previous studies have shown that the pedestrian making crossing judgments primarily on vehicle distances (Lobjois and Cavallo, 2007; Oxley et al., 2005, 2006). When the approaching vehicle speed increases, the pedestrian tends to overestimate the distance between them and thus reduces the time remaining for walking across the road safely. The observed decrease in the time gap as vehicle speed increased resulted in a smaller safety margin and a higher percentage of unsafe decisions regardless of PD or control subject.

To both the normal control group and the Parkinson’s patients training exhibited significant help. Post training, both groups were able to understand and effectively increase the success rate in road crossing. However, one month after the training, the Parkinson’s patients showed a significant deterioration in safe margin training. Safety margin training followed the study by Dommes et al., (2012) and took normal elderly as subjects, where similar results to Dommes et al., (2012) were observed on the safety margin training. However, such training was not helpful to Parkinson’s disease patients. The primary reason was due to the higher severity of damage in the internal clock of Parkinson’s patients (Pastor et al., 1992). Therefore, the 1.5 second judgment quickly deteriorated after the training, ineffective in sustaining for more than one month.

Reference


