THE EFFECTS OF TAI CHI ON SIMPLE AND CHOICE REACTION TIME IN OLDER ADULTS

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Angelyn J. Frankenberg, B.A.

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ABSTRACT

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by

ANGELYN J FRANKENBERG, B.A.

Southwest Texas State University

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SUPERVISING PROFESSOR: Lisa K. Lloyd

Regular exercise can reduce the impact of aging on physical health and may also have cognitive benefits. This study investigated the effects of 8 weeks of Tai Chi on static balance, simple reaction time (SRT), and choice reaction time (CRT). The experimental group consisted of 1 male and 5 female residents of a retirement community (age = 83.3 $\pm$ 5.2 years, range = 74-88). The TC class met 3 times per week for 8 weeks (23 classes, mean number of classes attended = 19). The control group consisted of 2 male and 5 female residents of the same community (age = 83.3 $\pm$ 3.7 years, range = 78-88), who did not take part in the Tai Chi class. Pretests and post-tests were conducted for static balance, SRT, and CRT. No significant changes in balance time or SRT were noted for either group, however, the TC group's CRT was 15% faster on the post-test than on the pretest (pretest CRT = 718.8 $\pm$ 133.3 ms; post-test CRT = 610.0 $\pm$ 124 1 ms) These results indicate that Tai Chi practice may contribute to improved processing speed in older adults.

CHAPTER I

INTRODUCTION

Purpose of the Study

The population of the United States is aging. In the year 2000, there were approximately 35 million Americans 65 years of age and older. The U.S. Census Bureau projects that by 2030 this number will double and that people age 85 and up will be the fastest growing segment of the population (1). As more people live longer, multiple disciplines will continue to investigate the complex aging process in order to enhance this age group's health and quality of life.

Numerous studies have found that physical activity can help prevent, reverse, or lessen the effects of many diseases and conditions once thought to be inevitable with aging. Strength training helps prevent osteoporosis (2) and reduce muscle loss (3), while aerobic exercise improves cardiovascular health (4, 5). Evidence also continues to grow that older adults, including those in their eighties and nineties, can safely participate in regular exercise (6).

Tai Chi (TC), a traditional Chinese form of exercise, has gained popularity as an activity that can expose older individuals to the benefits of exercise with reduced risk. There are many Tai Chi styles, but all are characterized by slow, coordinated movement sequences known as postures. Essential elements of all

Tai Chi styles include focused breathing and a slow, but continual shifting of body weight from one leg to the other (7-9). While scientists know considerably more about the physical than the psychological benefits of exercise, interest in the latter is growing. Age related declines in specific cognitive areas are well documented and include reaction time slowing, losses in problem-solving ability, and declines in memory (12-14).

A review of the relevant literature has revealed no previous investigations of the possible effects of Tai Chi on reaction time (RT) in elderly individuals. However, RT is an important aspect of skills such as driving that contribute to independent living. Therefore, this inquiry represents the merging of two major themes pertaining to senior adult fitness: 1) Tai Chi's history as a viable, effective exercise mode for senior adults, and 2) ongoing research into the possible effects of physical activity on preserving and improving cognitive function in the aging.

Definition of Terms

1. Reaction Time (RT) – the time between the presentation of a stimulus and the initiation of a response.
2. Simple Reaction Time (SRT) – reaction time involving one stimulus and a single, specified response.

3. Choice Reaction Time (CRT) – reaction time involving more than one stimulus, each with a specified response.
4. Tai Chi – traditional Chinese exercise mode consisting of slow, coordinated movement sequences (postures) that are executed in a continuous, flowing manner. There are many styles of Tai Chi that vary in complexity and number of postures. This study utilized the Yang Short Form, which includes 37 postures. Because of the short duration of the class, participants performed Part I of the form (14 sequences). Additional postures from Part II of the Yang Short Form were added through the course of the study.

CHAPTER 2

METHODS

Participants

Tai Chi participants were recruited from a group of 56 residents of a retirement community who attended an informational meeting Twenty-one of these residents expressed interest in participating in the study The low number of volunteers precluded randomization or matching by age and gender Thirteen individuals obtained the required medical clearance, and 11 began the Tai Chi class Six participants (age = 83.3 $\pm$ 5.2 years, range = 74-84) completed the class, which met 3 times/week for 8 weeks Four participants dropped out because of scheduling conflicts. One participant stopped attending because of dizziness, which was not related to the Tai Chi The average number of classes attended was 19 The control group consisted of 2 male and 5 female residents of the same community (age = 83.3 $\pm$ 3.7 years, range = 78-88), who did not take part in the Tai Chi class.

This study was approved by Southwest Texas State University's Institutional Review Board and written informed consent was obtained from all subjects prior to participation.

Procedures and Apparatus

Rating of Physical Activity Level

Participants indicated their current level of physical activity by completing the NASA Scale of Physical Activity, which rates activity levels from 0-7 (10).

Reaction Time Testing

Simple reaction time (SRT) and choice reaction time (CRT) were measured for each subject at the beginning of the study (pretest) and at its conclusion (post-test). Participants were tested one at a time. Following a demonstration of the reaction time equipment, each participant received 10 practice trials, which were followed by 10 test trials. Means of the best 8 test trials were used for analysis.

SRT was measured with a Lafayette Multi-Choice Reaction Time Apparatus, Model 63014A, manufactured by the Lafayette Instrument Company of Lafayette, IN. Participants were instructed to place a finger on the center of 3 levers and to press the lever when a light turned on. Foreperiods of 1 to 3 seconds duration were randomly assigned to the test trials and were the same for each subject.

CRT was measured with a Lafayette Visual Choice Reaction Time Apparatus, Model 63035A, manufactured by the Lafayette Instrument Company of Lafayette, IN. Participants were instructed to place two fingers of each hand on buttons below 4 different light bulbs. For each trial, participants responded by pressing the button corresponding to the light that turned on. Colors were randomly assigned for the test trials and were the same for each subject.

Balance

Static balance time on each foot was also tested at the beginning and again at the end of the study. A Dekan Automatic Performance Analyzer, Model 741A, consisting of a timing unit and 2 switchmats, was used to determine how long (sec) participants could stand on one foot. The switchmats were connected to the timing unit so that only 1 mat was active at a time. Subjects were instructed to stand normally with each foot on one of the mats. The timer started when the foot on the active mat was lifted and stopped when the foot was returned to the mat. Subjects chose which side to test first and performed 3 practice trials and 5 test trials. Means of the best 3 test trials were used for analysis.

Tai Chi Class

The classes were led by an instructor trained in Tai Chi. Each session consisted of approximately 10 minutes of stretching, 15 minutes of TC warm-ups (breathing exercises and practice in specific stances and postures), and 20-25 minutes of continuous TC. After 4 weeks, the TC group members indicated their exercise intensity on the Borg Rating of Perceived Exertion Scale (11). This scale rates exertion from 6 to 20, with 6 representing no physical exertion at all and 20 representing maximum exertion. The TC participants' mean RPE rating was 10.5 ± 1.5.

The control group members were instructed to maintain their current level of physical activity.

Design and Analysis

A 1-way repeated measures ANOVA was used to analyze changes in SRT, CRT, and static balance time. Tai Chi participation was the independent variable and SRT, CRT, and balance time were the dependent variables. Overall group differences were analyzed with a 1-way MANOVA.

CHAPTER 3

RESULTS

The purpose of this study was to determine if 8 weeks of Tai Chi practice would have an effect on simple reaction time (SRT), choice reaction time (CRT), or static balance in a group of elderly individuals.

Table 1 presents the group means for the three items in question. MANOVA revealed no significant overall differences (pretests and post-tests combined) between the TC and control groups for either balancing on the right leg ($F(1,22) = 0.004$, $p = 0.9517$) or balancing on the left leg ($F(1, 22) = 1.922$, $p = 0.1795$). The experimental group's overall SRT's were significantly slower than those of the control group (Wilk's Lambda = 0.594, $F(4,19) = 3.248$), $p = .0344$). The combined pretest and post-test mean for the experimental group was 363.7 $\pm$ 74.6 ms and 306.29 $\pm$ 56.14 ms for the control group. There was no overall (pretests and post-tests combined) difference in CRT between the TC and control groups ($F(1,22) = 3.741$, $p = .0661$).

The primary research questions in the study concerned the effect of TC on improvements in balance, SRT, or CRT compared to the control group. For SRT, even though the experimental group was significantly slower than the control group, there was no significant difference in their pretest to post-test change ($F(1, 11) = 1.79$, $p = .2078$). The control group's SRT time increased by 23.71

Table 1. — Reaction Time (ms) and Balance (sec) Mean ± SD			
	Control	TC	All
Age	83.29 ± 3.73	83.33 ± 5.16	83.31 ± 4.25
PAR	1.71 ± 0.95	1.5 ± 0.5	1.62 ± 0.77
Intensity (RPE)	NA	10.5 ± 1.5	NA
SRT - Pre	294.43 ± 50.32	373.50 ± 78.25	330.92 ± 74.17
SRT - Post	318.14 ± 63.00	366.33 ± 66.17	340.39 ± 66.59
CRT - Pre	555.00 ± 74.71	718.83 ± 133.33	630.62 ± 132.00
CRT - Post	569.57 ± 76.90	610.00 ± 124.12	588.23 ± 99.08
Bal R - Pre	10.856 ± 14.678	7.946 ± 5.724	9.643 ± 11.475
Bal R - Post	9.149 ± 12.800	11.466 ± 11.928	10.114 ± 11.938
Bal L - Pre	8.201 ± 6.281	12.192 ± 10.544	9.864 ± 8.135
Bal L - Post	8.030 ± 5.840	13.049 ± 10.806	10.121 ± 8.231

ms, from 294.43 ± 50.32 ms on the pretest to 318.14 ± 63.00 ms on the post-test. The TC group's mean times were 373.50 ± 78.25 ms on the pretest and 366.33 ± 66.17 ms on the post-test, a difference of 7.17 ms. The lack of improvement in SRT is demonstrated in Figure 1.

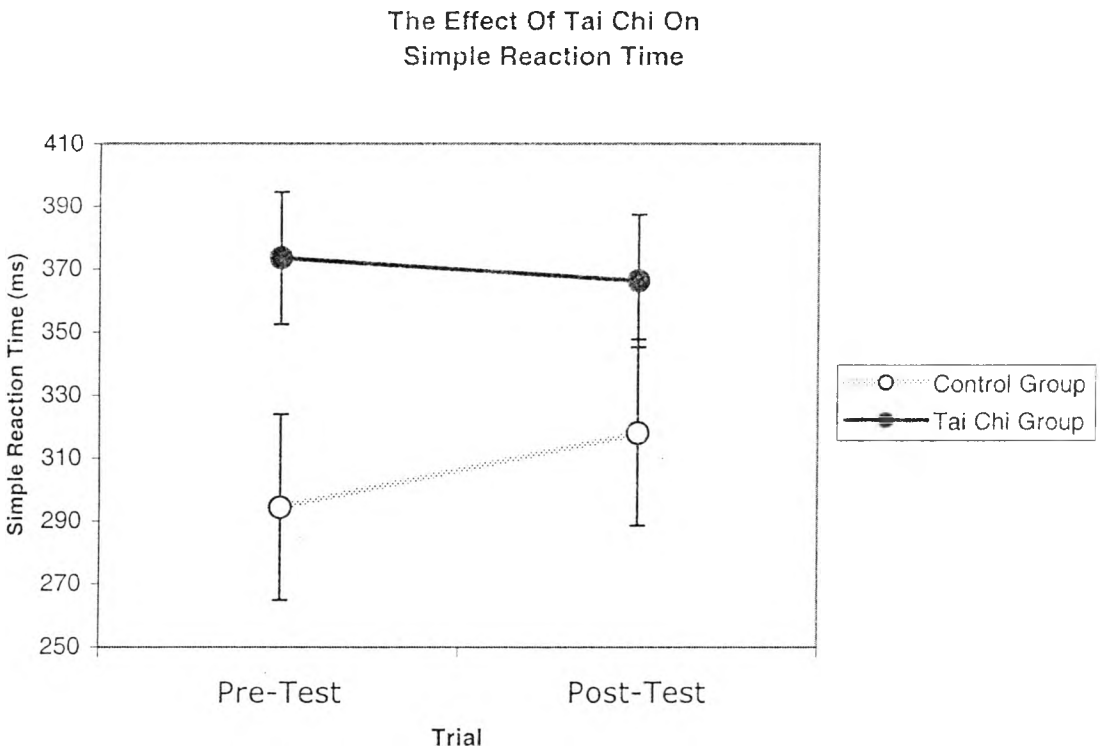

Figure 1.— The Tai Chi group's simple reaction time (SRT) was not significantly different on the post-test than on the pretest.

There was, however, a significant difference in CRT change between the TC and control groups ($F(1,11) = 15.406$, $p = 0.0024$. The control group averaged 555.00 ± 74.71 ms on the pretest and 569.57 ± 76.90 on the post-test, an increase of 14.57 ms. The TC group's post-test time of 610.00 ± 124.12 was 108.83 ms faster than their pretest time of 718.83 ± 133.33 ms. The training effect for CRT is demonstrated in Figure 2.

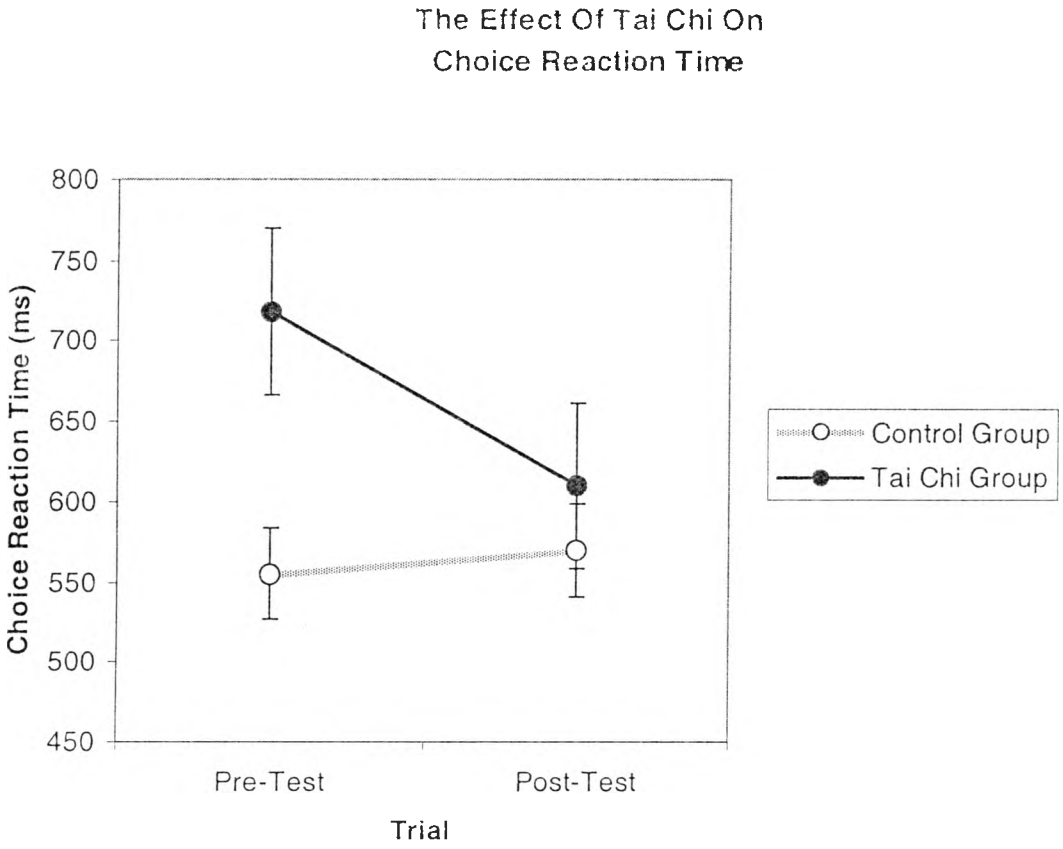

Figure 2.—The Tai Chi group's choice reaction time (CRT) was 15% faster on the post-test than on the pretest.

For balancing on the right leg, no significant differences were observed ($F(1,10) = 2.03$, $p = .185$) in the changes in the control group from the pretest (10.86 $\pm$ 14.68 ms) to the post-test (9.15 $\pm$ 12.80 ms) compared to changes in the treatment group from the pretest (7.95 $\pm$ 5.72 ms) to the post-test (11.47 $\pm$ 11.93 ms). For balancing on the left leg, no significant differences were observed ($F(1,10) = 0.68$, $p = .43$) in the changes in the control group from the pretest (8.20 $\pm$ 6.28 ms) to the post-test (8.03 $\pm$ 5.84 ms) compared to changes

in the TC group from the pretest (12.19 $\pm$ 10.54 ms) to the post-test (13.05 $\pm$ 10.81 ms).

CHAPTER 4

DISCUSSION

This study investigated the effects of Tai Chi on static balance and reaction time in a group of older adults residing in a retirement community. Since a possible connection between TC and RT is a new area of research, this study should spark additional inquiries.

The TC group exhibited no post-test improvements in static balance, possibly because of the study's short duration. Previous research that has indicated a positive effect of TC on balance have employed interventions of 10 weeks or longer (9, 13). Others have been cross-sectional investigations of long-term TC participants (14, 15). Also, since TC is movement-based, it may affect dynamic balance more than, or sooner than, static balance.

The central question in this study, however, was whether Tai Chi practice would result in improvements in simple and choice reaction time in the elderly. No significant improvement in SRT was found for the TC group compared to the control group; however, the TC group had significantly greater improvement in CRT compared to the control group. This finding may indicate that Tai Chi practice can have a positive effect on CRT in older adults.

The mean NASA Scale of Physical Activity ratings (control group, 1.7; TC group, 1.5) were not significantly different for the two groups ($F(1,11) = 0.24$,

p = .64). However, two members of the control group rated themselves at level 3, the highest of all the study participants. These individuals also had the fastest pretest SRT's (224 ms and 236 ms) and CRT's (448 ms and 489 ms) of all the study participants. These observations are in accordance with previous studies that have found faster reaction times in physically active older adults (18-20).

While the TC group experienced significant improvement only in CRT, 4 of the 6 members of the group scored better on SRT post-tests and all 6 scored better on CRT post-tests. There was no consistent pattern of improvement in the control group.

Although this study was limited by the small, non-randomized sample, its findings clearly indicate the need for further study of the possible connections between Tai Chi and reaction time. Future studies should employ longer periods of training with larger samples. With randomization, researchers can create TC and control groups that have statistically equal RT's at the outset, as well as control for factors such as gender and amount of physical activity.

Reaction time is an important aspect of skills such as driving. Improvement of RT can possibly help elderly adults preserve and enhance their independence during the aging process. In addition, RT may indicate efficiency in broader cognitive functions. Therefore, this study's findings, along with continuing research on cognitive benefits of other types of exercise, suggest that exercise may have a central role in cognitive function. Further investigation in this area can contribute to preserving independence and quality of life among aging adults.

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APPENDIX A

REVIEW OF THE LITERATURE

REVIEW OF THE LITERATURE

Effects of Exercise In Older Adults

Numerous studies have shown that exercise elicits physiological and psychological changes in older adults that can contribute to improved functional capacity and independence. The American College of Sports Medicine (ACSM) groups these effects into 4 types: 1) cardiovascular health, 2) strength and bone density, 3) flexibility, balance, and postural stability, and 4) psychological function, including both affective and cognitive areas (6).

Age-associated changes in the cardiovascular system affect senior adults' responses to physical exertion. Aerobic capacity, quantified by maximal oxygen consumption (VO_{2max}), decreases by 5 to 15% per decade after age 25 (21). Maximal heart rate decreases by 6 to 10 beats per minute (bpm) per decade, and contributes to lower cardiac output in older adults (22). Plasma, red blood cell, and total blood volumes also decrease with age (23), while blood pressure and vascular resistance increase (22).

The prevalence of cardiovascular disease increases with age, but considerable evidence indicates that endurance training has a protective effect on the cardiovascular system. One study of a moderate intensity program found VO_{2max} increases of 24% in men and 21% in women after 1 year (24). The participants, aged 60-72, exercised 4 days/week for approximately 45 minutes.

This study corroborates the 10 - 30% VO_{2max} increase with endurance training reported by Kohrt (25). This is the same relative improvement that occurs with endurance training in younger adults (25).

Aerobic training also results in improved lipid profiles. These changes, which may be secondary to reduced body fat, include increases in HDL and decreases in triglycerides and in the ratio of total cholesterol to HDL (26, 27). Aerobic and strength training exercise also improve glucose tolerance and insulin sensitivity in the elderly (28, 29).

The benefits of regular aerobic exercise reduce the risk of cardiovascular disease. For individuals who already have cardiovascular disease, endurance training can contribute to a better prognosis. According to the ACSM, absolute improvements in risk factors for cardiovascular disease may require moderate or high intensity training. Long-term light- to moderate-intensity exercise, however, may slow the rate of age-related declines in cardiovascular function, which can contribute to longevity and quality of life (6).

Decreased functional capacity and mobility and an increased likelihood of falls and fractures are important considerations for the independence and quality of life among older adults. Falls are strong predictors for placement in a skilled nursing facility. One prospective study considered nursing home admissions among 1103 people over 71 years of age. In a 3-year period, 133 participants were admitted to nursing homes. The population attributable risk of long-term admission was 13% for those who experienced one noninjurious fall, 3% for

individuals with two or more noninjurious falls, and 10 percent for those who had at least one fall causing serious injury (30).

Resistance exercise can help prevent falls and fractures in aging adults by improving muscular strength. Age-associated sarcopenia, loss of muscle mass, typically begins after age 30, and is accompanied by increases in intramuscular fat. The reduction in density occurs primarily in Type II muscle fibers, which average 60% in young sedentary men and decrease to less than 30% after age 80 (31). These reductions relate directly to age-associated decreases in strength, which affect walking ability and performance of activities of daily living (ADL's) among elderly individuals.

Progressive resistance training elicits the same or greater strength gains in older as in younger adults. Studies have demonstrated that 3 - 4 months of training can result in two to threefold increases in muscular strength (3, 32). Strength training can also maintain or increase bone density in aging adults (2), thereby reducing the risk of fractures and falls.

Reduced postural stability occurs with aging and can contribute to decreased mobility and an increased risk of falling (33). Multiple factors influence postural stability, and exercise is one treatment that has been shown to improve this response in senior adults. The National Institute on Aging sponsored the FICSIT (Frailty and Injuries: Cooperative Studies of Intervention Techniques) investigations in an effort to delineate methods that might reduce the number of falls and resulting bone fractures in senior adults. These trials considered walking, dancing, and other types of exercise as treatments. A

meta-analysis of these trials found a decrease in the risk of falls among exercise participants (34).

Changes in muscle, bone, and connective tissue properties cause flexibility, which refers to the range of motion in one of more joints, to decline with age (35). Studies have reached different conclusions on the effects of exercise on flexibility and no consistent prescription for this area exists. However, the ACSM recommends walking, aerobic dance, and stretching as methods of increasing joint range of motion in senior adults (6).

Researchers have also investigated the effects of exercise on psychological function in the elderly. The Alameda County study (36) and the Iowa 65+ Rural Health Study (37) both reported an inverse relationship between physical activity and depressive symptoms.

A detailed look at the literature on the connection between exercise and cognitive function comprises the last section of this review.

Tai Chi Studies

Tai Chi has gained popularity as a fitness activity for older adults in recent years, largely because of its slow, coordinated movement sequences. TC sequences are characterized by diaphragmatic breathing, low impact foot placement, and a continual, but slow, shifting of body weight from one leg to the other (7-9). These characteristics, combined with the relative ease and low cost of implementing a TC program, may make this exercise mode particularly suitable for seniors, including those who have previously been sedentary (7, 38).

Some researchers report a higher degree of motivation among seniors to begin and continue a Tai Chi program than other types of activity, due partly to the mind-body connection and relaxation associated with this exercise method (7).

Researchers have found Tai Chi to improve various aspects of physical fitness in the older adult population. Some studies have reported cardiorespiratory benefits, including improved VO_{2max} and reduced heart rate and blood pressure, in TC participants (8, 9). Significantly lower ventilatory frequency has been reported in experienced Tai Chi practitioners, indicating that longer-term involvement in TC might help improve ventilatory efficiency in the elderly (38).

Tai Chi also has applications in decreasing the risk of falls and fractures among aging adults. Schaller reported a significant improvement in balance among older adults who participated in 10 weeks of TC training (9). Another clinical trial linked TC training to improved balance, increased postural stability, and an overall reduction in the risk of falls and fear of falling among seniors (15).

Another study undertaken to reduce falls and improve performance of daily living activities among older adults focused on knee extensor strength and endurance. Thirty-two subjects, aged 53-64, completed a 6-month Tai Chi program (15 men, mean age 62.5; 17 women, mean age 60.0; average attendance, 3-4 times/week). Post-tests showed increases in concentric and eccentric knee extensor peak torque and endurance in both male and female subjects (8).

Other researchers have reported Tai Chi benefits in motor control that directly impact elderly individuals' performance of daily living activities. One study investigated arm movement force variability in an aiming task (39). Seniors who completed an 8 week TC class ($n = 12$, $M = 79.3 \pm 2.4$) exhibited less variability of force than a group who engaged in walking or jogging for the same time period ($n = 8$, $M = 79.5 \pm 1.9$).

Exercise and Cognition

A review of previous studies of the association between physical activity and cognitive function further illustrates the rationale behind the current investigation. Research has developed 3 main theories about the associations between exercise and cognitive function. Studies of the effects of exercise on reaction time (RT) and other processing speed measurements suggest that physical activity leads to increased efficiency in the central nervous system (12).

Another proposed explanation is that age-related deterioration in cardiovascular function results in reduced oxygen delivery to the brain, which causes cognitive declines. Some research indicates that aerobic exercise may improve cognitive function by increasing cerebral circulation (12, 41).

A third possible connection between exercise and cognition involves structural plasticity and biochemical processes in the central nervous system (12, 40). Animal studies that have shown increases in brain weight, capillary growth, and neurochemical activity with prolonged physical exercise support the idea that fitness may cause changes in neurochemical processes and brain structures that

result in improved cognitive function (12, 40). Elsayed and colleagues (42) suggested that the increased use of fatty acids for physical activity makes more glucose available for improved CNS function. In a recent study of 55 subjects between the ages of 56 and 79, Colcombe et al. (43) showed that physically fit older adults had maintained greater brain tissue density than their sedentary counterparts.

Cross-sectional Studies

Spirduso first investigated possible effects of physical activity on RT in a 1975 cross-sectional study (18). Findings indicated no significant RT differences between active and sedentary young subjects (ages 20-30), but did reveal significant RT differences between active and sedentary older adults (ages 50-70). Further investigations by Spirduso and Clifford (44) and Chodzko-Zadjko and Ringel (45) corroborated these results. Rikli and Busch also found similar results in their 1986 study of the influence of age and activity level on motor performance in women (18).

In 1988, Baylor and Spirduso reported their findings on the effects of aerobic exercise on RT in older women (19). In this study, the researchers used electromyography (EMG) to divide simple and choice reaction time into 2 components: 1) premotor time (PMT) – the period between stimulus presentation and initiation of action potentials in the applicable muscles, and 2) contractile time (CT), sometimes referred to as motor time – the period of actual muscle contraction. Dividing RT into these components allowed Baylor and Spriduso to

determine that the effects of age and activity level on RT are primarily in PMT, not in CT. Since PMT is thought to represent central effects, while CT depends on the peripheral nervous system, this study appears to indicate a connection between aerobic exercise and central nervous system processing.

In 1989, Clarkson-Smith and Hartley (48) extended the research to include assessment of a wide range of cognitive functions, including memory, problem solving, and attentional capacity. They found significantly better cognitive performance in older high-fit adults than in older low-fit adults.

In spite of repeated associations between physical fitness and mental functions, various aspects of these cross-sectional studies limited their generalizability. No consistent measures of physical fitness were employed; rather, subjects self-reported their activity levels. Since participants had engaged in different types of physical activities, researchers could not draw conclusions regarding exercise prescription for aging individuals. Another question about cause and effect remained. Although results suggest that physical activity prevented some of the cognitive decline generally associated with aging, they do not eliminate the possibility that individuals with particular physiological and motor characteristics chose more active adult lifestyles.

Intervention Studies

Limitations of cross-sectional research underscored the need for clinical studies of exercise and cognition. Elsayed et al. (42) conducted an investigation in which subjects were divided into four groups following an initial fitness

assessment: 1) high-fit, young, 2) high-fit, old, 3) low-fit, young, and 4) low-fit, old. Intelligence tests were administered during the first and last weeks of a 4-week program of mixed exercises. Improvements in fluid intelligence, which involves reasoning and abstraction, were reported. However, the researchers indicated that improvements could have been due to affective factors such as motivation, rather than physiological factors.

Perrig-Chiello and associates conducted research using eight weeks of resistance training as the intervention (49). The forty-six subjects in this study had a mean age of 73.2 years, and the experimental group showed significant improvements in free recall and recognition. A reassessment of cognitive and other variables one year later yielded similar results; therefore, the researchers concluded that exercise effects were positive and long-term.

Due in part to established links between cognitive performance and cardiopulmonary function (41), many intervention studies have focused on aerobic exercise. In 1984, Dustman et al. performed a training study that randomly divided 43 sedentary subjects into three groups: strength and flexibility training, aerobic exercise, and a non-exercise control group. After 4 months, the strength and flexibility group had increased their aerobic capacity by 11% compared to a 27% increase for the aerobic group. Cognitive function post-tests showed significant improvements for the aerobic exercisers in four areas, while the strength training and control groups experienced little or no improvement (50).

Two other aerobic exercise intervention studies failed to support Dustman's conclusion that aerobic exercise had positive effects on specific types of cognition. Blumenthal, Emery, and Madden (26) carried out an investigation with subjects age 60-83. Four months of training yielded an 11.6% increase in aerobic capacity, but no significant training effect was evident in memory search, word comparison, and dual task tests. A 1990 study by Panton and colleagues supported these findings (51). Researchers assigned 49 adults, ages 70-79, to aerobic, strength and flexibility, and non-exercise groups. Aerobic capacity in the first group increased by 20%; however, these subjects attained no significant improvement in cognitive performance.

The Dustman, Blumenthal, and Panton investigations all looked at exercise as an intervention and all used VO_{2max} to determine aerobic fitness. However, different levels of aerobic capacity improvement and the use of different cognitive tests may have contributed to the conflicting results.

Hawkins, Kramer, and Capaldi (52) designed their inquiry to measure similar cognitive items as the Blumenthal study (26). Thirty-six older adults were divided into an aerobic exercise group and a non-exercise control group. The researchers reported significant improvements on dual-task items for the exercise group, but not the control group, on post-tests administered after ten weeks. Although both studies assessed performance on dual-task items, the Hawkins study placed time limits on them, while the previous study did not. Therefore, Hawkins and associates suggested that their test items demanded more attention than corresponding items in the Blumenthal study. They and

other researchers have concluded that aerobic exercise does improve some cognitive functions, and that attentionally demanding tasks are the most responsive to these effects (26, 52).

Two studies that tested exercise as an intervention to improve RT in older adults focused on strength and flexibility in addition to aerobic training. In a 3-year exercise program, previously sedentary women between the ages of 57 and 85 exhibited improvements in both SRT and CRT (53). Another study considered the effects of a short-term strength and endurance regimen on SRT. This 10-week intervention found small, but significant improvements in SRT in a group of 17 men and 27 women aged 50 to 75 years (mean = 62.4 $\pm$ 6.3) (54).

An examination of possible relationships between Tai Chi and reaction time is warranted by previous studies of exercise and cognition. Considerable research has confirmed an association between physical activity and RT (10, 12, 16-18), but the small number of intervention studies (51, 52) demonstrate the need for additional research in this area. As a first step in determining if the beneficial effects of Tai Chi extend to cognitive areas, this study may contribute to improving the quality of life for aging adults.

APPENDIX B

INFORMED CONSENT

MEDICAL RELEASE

INFORMED CONSENT

THE EFFECTS OF TAI CHI ON SIMPLE AND CHOICE REACTION TIME IN OLDER ADULTS

1. DESCRIPTION AND PURPOSE OF STUDY

This study will test participants' reaction time (RT) and balance time on one foot before and after a course of Tai Chi (3 times per week for approximately 10 weeks). The purpose of the research is to find out if RT and balance time improve with Tai Chi (TC) participation. A short-term memory test may also be administered before and after the TC class. A self-assessment of physical activity may be included to help determine if any differences in test results are related to general physical activity levels.

2. PROCEDURES

Tai Chi is an ancient Chinese form of exercise that consists of slow, coordinated movement sequences. These sequences are characterized by deep breathing, low impact foot placement, and a continual, but slow shifting of body weight from one leg to the other. Experimental and control groups will be assigned in one of two ways:

1) Participants who volunteer for the study will be randomly assigned to one of two groups: a) the exercise group that will take part in the 10-week Tai Chi class, and b) the non-exercise, control group that will not take part in the TC class.
2) Volunteer Tai Chi participants will be matched by age and gender to controls who will not take part in the TC class.

RT and balance time on one foot will be measured for both groups before the TC class begins, and again after it ends.
A short-term memory test and a self-assessment of physical activity may also be included.

3. POSSIBLE RISKS AND DISCOMFORTS

Tai Chi

Older adults who are in general good health can usually participate in TC safely and without marked physical discomfort. With any physical exertion, however, abnormal blood pressure or heart rate responses (such as fainting, irregular, fast or slow heart rhythm) may occur. Falls, while not likely, are potentially serious. Muscle or joint injury, fatigue, and/or soreness are also possible. Every effort will be made to minimize these risks by monitoring heart rate and blood pressure during the 10 week Tai Chi class, by careful observation, and by guidance in properly performing the TC movement sequences. Additionally, participants must obtain physician approval to participate in the TC class. This is a precaution to screen out individuals who may: a) have bone or joint problems that would make TC movements unsafe for them, or b) have medical conditions or be on medications that could negatively affect balance.

RT Testing

These tests are simple procedures involving pressing a lever in response to a stimulus (a light turning on), and they pose virtually no risk to participants.

Balance Time Testing

These tests will be performed using timing mats, and test administrators will stand on either side of participants during testing to prevent falls.

Short-term Memory Testing

This test will be oral and/or written and will pose no physical risk to participants. Individuals may have access to their own results, however, test administrators (the student researcher and up to three assistants) will protect your privacy by using ID numbers, not names, for recording results.

Self-Assessment of Physical Activity

This assessment will be a written scale on which participants indicate their current level of physical activity. It will pose no physical risk.

4. RESPONSIBILITIES OF THE PARTICIPANT

You are responsible for obtaining your physician's approval for participation in the TC class. Information that you may withhold about your health status or previous experiences of heart-related symptoms (such as shortness of breath with low-level activity, pain, pressure, tightness, heaviness in the chest, neck, jaw, back and/or arms) with physical effort may affect your ability to safely participate in any exercise program, including Tai Chi. You are also responsible for immediately reporting any unusual or abnormal feelings of discomfort and/or pain during or after exercise to your instructor.

5. BENEFITS

Research has shown that, for the majority of older adults, being *inactive* carries more health risks than participating in physical activity that meets your needs. Previous studies have reported various types of benefits for seniors practicing Tai Chi, including improved balance, reductions in heart rate and blood pressure, and stress reduction. Participants in this study may experience benefits in these areas. By taking part in the RT and short-term memory testing, you will help add to the body of knowledge about possible links between exercise and cognitive function.

6. CONFIDENTIALITY

The student researcher/TC instructor and other test administrators will know your individual test results. This information will also be available to the three members of the student researcher's thesis committee, but no other individuals will have access to unpublished results of the study. ID numbers will be assigned to participants. This procedure will protect your privacy by preventing your name from being linked to other personal information (such as your age) and to your test results. Individual test results will not be disclosed to other parties without your written permission.

7. INQUIRIES

Any questions about Tai Chi, the tests, or your rights are encouraged. You may direct questions to:

1. Angelyn Frankenberg, Principal Investigator & Tai Chi Instructor
   (210) 326-0568
   E-mail: angye.f@netzero.net

2. Lisa K. Lloyd, PhD; Faculty Supervisor & Thesis Committee Chair
   Southwest Texas State University
   (512) 245-8358
   E-mail: ll12@swt.edu

8. FREEDOM OF CONSENT

Taking part in this study is voluntary. Participants are free to stop any exercise or test at any point, and may also withdraw from the study at any time without penalty.

****

My signature constitutes my consent to participate in this study. I understand that I am free to stop any exercise or test at any time, if I so desire. I also understand that I am free to withdraw from the study at any time, and that withdrawal will result in no penalty or loss of benefits to which I am otherwise entitled.

I have read this form, and I understand the possible risks and discomforts associated with the study. Knowing these risks and discomforts, I consent to participate in the study.

_____ _____

Signature of Participant Date

_____

Signature of Witness

Physician Approval For Tai Chi Study Participation

I have consulted with the following patient by phone or office visit concerning his/her ability to safely participate in a Tai Chi class for senior citizens that will meet 3 times/week for approximately 10 weeks. In my professional opinion, there is no medical reason that this person cannot safely participate in the class.

Participant's Name _____

Physician's Signature _____

Date _____

Please Print or Stamp: Physician's Name _____

Address _____

Telephone # _____

Fax # _____

For more information, contact:
Angelyn Frankenberg, Instructor - - - 210-326-0568 - - - angye.f@netzero.net

APPENDIX C

IRB

IRB Reference #03-0183

Synopsis of Proposal

The Effects of Tai Chi On Simple and Choice Reaction Time In Older Adults

1. This study will test reaction time (RT) in senior citizens before and after participation in a Tai Chi (TC) class (3 times/week for approximately 10 weeks). Balance time on one foot will be recorded before and after the TC class. A short-term memory test may also be administered before and after the TC class. Additionally, a self-assessment physical activity scale may be included to help determine if any differences in test results are related to participants' general physical activity levels The study will be conducted at The Meadows Retirement Community in San Antonio, TX. Potential subjects are in their 70's, 80's, and 90's (most are in their 80's), are in overall good health, and are of Hispanic or Caucasian ethnicity. The projected number of participants is 30 - 40, and the majority will be female. Criteria for inclusion will be volunteering to participate and obtaining physician approval in order to take part in the Tai Chi class. Experimental and control groups will be assigned by one of the following methods:

   1) Volunteer participants will be randomly assigned to two groups: a) the exercise group that will take part in the 10-week Tai Chi class, and b) the non-exercise, control group that will not take part in the TC class.
   2) Volunteer Tai Chi participants will be matched by age and gender to controls who will not take part in the TC class.

   I will recruit subjects during site visits. Information about TC, RT and balance time testing will be presented to small groups with individual follow-up as needed. I will also demonstrate TC sequences during these visits. Potential participants will be informed that randomization or subject matching will be utilized to create experimental (TC) and control (non-TC) groups. Volunteers will provide written informed consent (form attached).

2. Tai Chi is a mode of exercise that consists of slow, coordinated movement sequences. These sequences are characterized by deep breathing, low impact foot placement, and a continual, but slow shifting of body weight from one leg to the other. The popularity of TC among seniors may be due in part to these characteristics. Older adults who are in generally good health can usually participate in TC safely and without marked physical discomfort. Abnormal blood pressure or heart rate responses (e.g. fainting, irregular, fast or slow heart rhythm) may occur with any mode of exercise, but may be less likely during participation in Tai Chi than in other types. Falls, while not likely, are potentially serious. Muscle or joint injury, fatigue, and/or soreness are also possible.
   RT testing is a simple procedure involving pressing a lever in response to a stimulus, and poses virtually no risk to participants.

   Balance time on one foot will be measured using timing mats and two test administrators will stand on either side of subjects during these tests to prevent falls.

   A short-term memory test, if utilized, will be oral and/or written and will pose no physical risk to participants. Researchers will protect confidentiality of results to prevent psychological or legal risk.

   The self-assessment of physical activity will be a written scale on which participants indicate their current level of physical activity. It will pose no risk.

3. Physician approval will be required for taking part in the Tai Chi class (form attached). This requirement is intended to screen out potential subjects who may have medical conditions that preclude safe participation, such as: a) bone or joint problems that contraindicate the weight-shifting movements of TC, and b) conditions or medications that could negatively affect balance. I will explain that proper footwear and pants with intact hems that are not too long are essential to preventing falls.

   I am certified in CPR and will monitor subjects' heart rate and blood pressure responses during the course of the study.

   Participants' privacy will be protected by assigning ID numbers. Only my thesis committee and I will have access to the list of subjects' names and corresponding ID numbers.

   Previous studies have found benefits among senior Tai Chi participants such as improved balance, reductions in heart rate and blood pressure, and reduced stress. Participants in the current study may experience some of these benefits. By focusing on the question of whether TC participation will result in improvements in reaction time and short-term memory, this study may add to the current knowledge about possible relationships between exercise and cognitive function. The project may also benefit society in general by spurring further research in increasing independence, improving quality of life, and reducing health care costs for older adults.

   Study participants may experience some of the same benefits reported in previous Tai Chi studies. Potential risks of the current study will be reduced by precautions taken to screen subjects and to prevent falls by those who do participate. Therefore, it appears that possible benefits outweigh risks, both to the subjects and to society in general.

4 The study will take place at The Meadows Retirement Community; 730 Babcock Rd.; San Antonio, TX 78201; 210-734-1155. Eva Brown, Activities Director, has approved the project and her letter of approval will follow.

5. This study is being conducted for the thesis requirement for the Master of Education degree. Lisa K. Lloyd, Ph.D. is the Supervising Professor.

   Dr. Lloyd, who is also the chair of my thesis committee, has approved the study.

   This project has not been reviewed by another IRB.

6. Individuals who will have access to the unpublished results of this study are:

   Dr. Lisa Lloyd
   Dr. Darlene Schmidt
   Dr. John Walker
   Angelyn Frankenberg

   Up to 3 additional HPERD students may assist with test administration. They will have access to unpublished results only during testing.

APPENDIX D

DATA

TAI CHI DATA - Individual Participants

ID #	F=0 M=1	Age	PAR	RPE	SRT-Pre	SRT-Post	CRT-Pre	CRT-Post	Bal R-Pre	Bal R-Post	Bal L-Pre	Bal L-Post
E1	1	74	1	11	288	280	519	458	11.614	31.288	17.200	20.529
E2	0	88	2	11	348	415	778	618	2.848	2.080	2.599	1.841
E3	0	84	2	10	328	295	744	640	0.931	2.513	1.930	2.302
De	0	88	1	13	390	412	752	734	Declined	1.515	Declined	1.275
E5	0	82	1	9	371	360	618	468	14.003	12.575	27.102	25.999
E6	0	84	2	9	516	436	902	742	10.333	8.872	12.131	14.573
Mean		83.33	1.500	10.50	373.500	366.333	718.833	610.000	7.946	9.807	12.192	11.087
St. Deviation		5.16	0.548	1.52	78.250	66.165	133.330	124.123	5.724	11.416	10.544	10.795
C1	1	88	3		236	239	448	484	5.637	6.736	14.023	11.492
C2	1	81	1		273	296	526	627	43.138	37.794	18.703	16.499
C3	0	86	1		312	360	675	623	5.384	5.008	6.956	6.481
C4	0	82	3		224	248	489	443	12.343	5.232	9.469	13.602
C5	0	78	1		348	375	592	624	1.452	1.472	2.831	1.789
C6	0	81	2		329	402	583	624	6.177	6.149	3.098	4.009
C7	0	87	1		339	307	572	562	1.862	1.651	2.329	2.339
Mean		83.29	1.714		294.429	318.143	555.000	569.571	10.856	9.149	8.201	8.030
St. Deviation		3.73	0.951		50.322	63.001	74.708	76.896	14.678	12.800	6.281	5.840
Overall												
Mean		83.31	1.615	10.50	330.923	340.385	630.615	588.231	9.644	9.453	9.864	9.441
St. Deviation		4.25	0.768	1.52	74.167	66.588	132.001	99.075	11.475	11.676	8.135	8.254

PAR = Participants' self-rating of physical activity, NASA Scale of Physical Activity
RPE = Tai Chi participants' rating of exercise intensity - Borg RPE Scale

Tai Chi Data - Descriptive Statistics

Split By Treat = 1

	Mean	Std Dev	Std Error	Count	Min	Max	Number Missing
Age - Total	83 308	4 250	1 179	13	74 000	88.000	0
Age, 0	83 286	3 729	1 409	7	78 000	88 000	0
Age, 1	83 333	5.164	2 108	6	74 000	88.000	0
PAR, Total	1 615	0 768	0 213	13	1 000	3 000	0
PAR, 0	1 714	0 951	0 360	7	1 000	3 000	0
PAR, 1	1 500	0 548	0 224	6	1 000	2 000	0
RPE, 1	10 500	1 517	0 619	6	9 000	13 000	0
SRT-Pre, Total	330.923	74 167	20 570	13	224 000	516 000	0
SRT-Pre, 0	294 429	50 322	19 020	7	224 000	348 000	0
SRT-Pre, 1	373 500	78 250	31 946	6	288.000	516 000	0
SRT-Post, Total	340 385	66 588	18 468	13	239 000	436 000	0
SRT-Post, 0	318 143	63 001	23 812	7	239 000	402 000	0
SRT-Post, 1	366 333	66 165	27 012	6	280 000	436 000	0
CRT-Pre, Total	630 615	132.001	36 610	13	448 000	902 000	0
CRT-Pre, 0	555 000	74 708	28 237	7	448 000	675 000	0
CRT-Pre, 1	718 833	133 330	54 432	6	519 000	902 000	0
CRT-Post, Total	588 231	99 075	27 478	13	443 000	742 000	0
CRT-Post, 0	569 571	76 896	29 064	7	443 000	627 000	0
CRT-Post, 1	610 000	124 123	50 673	6	458 000	742.000	0
Bal R-Pre, Total	9 643	11 475	3 313	12	0 931	43 138	1
Bal R-Pre, 0	10 856	14 678	5 548	7	1 452	43 138	0
Bal R-Pre, 1	7 946	5 724	2.560	5	0 931	14 003	1
Bal R-Post, Total	10 114	11 938	3 446	12	1 472	37 794	1
Bal R-Post, 0	9 149	12 800	4 838	7	1 472	37 794	0
Bal R-Post, 1	11 466	11 928	5 334	5	2 080	31 288	1
Bal L-Pre, Total	9 864	8 135	2.348	12	1 930	27 102	1
Bal L-Pre, 0	8 201	6 281	2 374	7	2 329	18.703	0
Bal L-Pre, 1	12 192	10 544	4 716	5	1 930	27 102	1
Bal L-Post, Total	10 121	8 231	2 376	12	1 789	25.999	1
Bal L-Post, 0	8 030	5.840	2 207	7	1 789	16.499	0
Bal L-Post, 1	13 049	10 806	40833	5	1 841	25 999	1

ANOVA Table for Age

	DF	Sum of Squares	Mean Squares	F-Value	P-Value	Lambda	Power
Treat = 1	1	007	007	3 718 E-4	0 9850	3 718 E-4	0 050
Residual	11	216 762	19 706				

Means Table for Age
Effect: Treat = 1

	Count	Mean	Std Dev	Std. Error
0	7	83 286	3 729	1 409
1	6	83 333	5 164	2 108

Fisher's PLSD for Age
Effect: Treat = 1
Significance Level: 5%

	Mean Diff	Crit Diff.	P-Value
0, 1	- 048	5 436	9850

MANOVA Table for Treat = 1

	Value	F-Value	Num DF	Den DF	P-Value
S	1 000				
M	0 000				
N	4 000				
Wilks' Lambda	977	118	2	10	8896
Roy's Greatest Root	024	118	2	10	8896
Hotelling-Lawley Trace	024	.118	2	10	8896
Pillai Trace	023	118	2	10	8896

Means Table for PAR
Effect: Treat = 1

	Count	Mean	Std. Dev	Std Error
0	7	1 714	951	.360
1	6	1 500	548	224

ANOVA Table for PAR

	DF	Sum of Squares	Mean Square	F-Value	P-Value	Lambda	Power
Treat = 1	1	.148	.148	.236	6370	236	072
Residual	11	6 929	630				

Fisher's PLSD for PAR
Effect. Treat = 1 Significance Level: 5%

	Mean Diff	Crit. Diff	P-Value
0, 1	214	.972	6370

VITA

Angelyn Frankenberg was born in Abilene, Texas, on September 30, 1955, the daughter of Estellene Valliant Frankenberg and Arthur Frankenberg. She received a Bachelor of Arts degree from McMurry University in 1978. Her growing interest in fitness in middle aged and older adults led her to pursue graduate studies at Southwest Texas State University, where she was named the Outstanding Graduate Student in Physical Education for 2001-2002. With Dr. Lisa Lloyd, Angelyn co-authored "The Effects of 30 Minutes of Light Intensity Exercise on Chronic Fatigue Syndrome (CFS) Patients," which was published in 2001 by International SportMed Journal.

Permanent Address: 3615 Lakefield Street
San Antonio, Texas 78230

This thesis was typed by Angelyn Frankenberg.