RESILIENCE THROUGH PARTNER WORK

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Literature for the workshop:

- Eggenberger, Patrick. et al. (2015). Clinical Interventions in Aging, p. 1335-1349
- Rough and Tumble Play. Website: https://pgpedia.com/r/rough-and-tumble-play
- Flanders, J. L., Leo, V., Paquette, D., Pihl, R. O. & Séguin, J. R. Rough-and-Tumble Play and the Regulation of Aggression: An Observational Study of Father-Child Play Dyads.

Clinical Interventions in Aging

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ORIGINAL RESEARCH

Does multicomponent physical exercise with simultaneous cognitive training boost cognitive performance in older adults? A 6-month randomized controlled trial with a 1-year follow-up

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Background: Cognitive impairment is a health problem that concerns almost every second elderly person. Physical and cognitive training have differential positive effects on cognition, but have been rarely applied in combination. This study evaluates synergistic effects of multicomponent physical exercise complemented with novel simultaneous cognitive training on cognition in older adults. We hypothesized that simultaneous cognitive–physical components would add training specific cognitive benefits compared to exclusively physical training.

Methods: Seniors, older than 70 years, without cognitive impairment, were randomly assigned to either: 1) virtual reality video game dancing (DANCE), 2) treadmill walking with simultaneous verbal memory training (MEMORY), or 3) treadmill walking (PHYS). Each program was complemented with strength and balance exercises. Two 1-hour training sessions per week over 6 months were applied. Cognitive performance was assessed at baseline, after 3 and 6 months, and at 1-year follow-up. Multiple regression analyses with planned comparisons were calculated.

Results: Eighty-nine participants were randomized to the three groups initially, 71 completed the training, while 47 were available at 1-year follow-up. Advantages of the simultaneous cognitive–physical programs were found in two dimensions of executive function. "Shifting attention" showed a time×intervention interaction in favor of DANCE/MEMORY versus PHYS (F[2, 68] =1.95, trend P=0.075, r=0.17); and "working memory" showed a time×intervention interaction in favor of DANCE versus MEMORY (F[1, 136] =2.71, trend P=0.051, R^2=0.006). Performance improvements in executive functions, long-term visual memory (episodic memory), and processing speed were maintained at follow-up in all groups.

Conclusion: Particular executive functions benefit from simultaneous cognitive–physical training compared to exclusively physical multicomponent training. Cognitive–physical training programs may counteract widespread cognitive impairments in the elderly.

Keywords: elderly, executive function, transfer, cognitive impairment, dance, video game

Introduction

A decrease in cognitive performance in old age is predominant in most individuals. This was confirmed by a large Italian epidemiological study demonstrating that aging-associated cognitive decline has a prevalence rate of 28% for people from 65 years to 84 years.[1] Additionally, another 17% of this Italian population (n=4,785) showed objective evidence of cognitive decline without cognitive complaints, which add up to a total of 45% of people showing some kind of cognitive impairment without dementia. Since cognitive decline potentially threatens independence and quality of life for older adults, prevention and treatment of cognitive impairment in the elderly has assumed increasing importance.[2] Two factors that may positively affect cognition in the elderly are physical activity and cognitive training.

Research has pointed out recently that physical activity may be relevant for healthy brain aging and may protect from cognitive decline and dementia.[3–7] Most physical intervention studies that focused on adaptations in cognitive performance, brain function, or brain structure, applied aerobic type exercise. Two meta-analytic studies reported that aerobic exercise is effective in increasing cognitive performance, in general, and executive function in particular.[8,9] More recent studies also found that strength and coordination training may positively affect cognitive abilities.[10,11] Voelcker-Rehage et al[11] demonstrated training specific functional plasticity in the brain based on functional magnetic resonance imaging data. Thereby, aerobic training increased activation in the sensorimotor network and coordination training led to a higher activation of the visuospatial network,[11] whereas strength training changed the hemodynamic activity of brain regions associated with response inhibition processes.[12]

Cognitive training studies have often shown highly task specific effects.[13–17] More widespread transfer effects were found when different cognitive abilities were combined in complex interventions or lifestyle changes.[18] Nevertheless, effects were often small, while aerobic training elicited both broad transfer and relatively large effects.[18] These findings led to the assumption that not only the combination of different cognitive abilities but also the combination of cognitive and physical training improves cognitive performance in old age to a greater extent than the training of an isolated ability.[5,7,18–22] Therefore, more and more studies pursue exactly this goal by administering a combined cognitive–physical training approach.

Some studies applied the physical and cognitive training sessions in a sequential manner,[23–26] whereas others performed the physical and cognitive training units simultaneously.[27–30] An advantage of simultaneous training designs might be that they include dual tasking and switching attention between the cognitive and physical activity. For instance, Theill et al[27] investigated the effects of simultaneous memory training and treadmill walking and revealed benefits in cognitive–motor dual-task walking compared to a single cognitive training and a passive control group. Virtual reality video game dancing represents a novel mode of simultaneous cognitive–physical training and has been applied by Pichierri et al.[28,29] Intervention groups demonstrated increased cognitive–motor dual-task performance in a stepping accuracy task[28] or during fast walking,[29] respectively. Nonetheless, interpretation of the existing studies on combined cognitive–physical training is often limited due to small sample sizes,[24,26,28,29] inconsistent training exposures between intervention groups,[23–25,28,29] or the lack of reference groups with only physical training.[27,28] Moreover, transfer to different cognitive domains was not assessed in some studies[28–30] and most interventions lasted for 4 months at most.[23,24,26–30] This duration might be too short since physical training interventions of 6 months or longer have shown most consistent effects on cognition.[3,8] Therefore, we suggest that the promising findings in previous research are worth further investigation.

This study aims to compare two variations of simultaneous cognitive–physical training with an exclusively physical multicomponent program and to evaluate the effects of these programs on cognition in healthy elderly people. We hypothesize, first, that simultaneous cognitive–physical training may create additional beneficial effects on cognition, and second, that the two cognitive–physical training variations may lead to differential cognitive adaptations. Based on previous findings, reported earlier, we expect cognition to improve in all three programs. Furthermore, we aim to investigate the performance maintenance 1 year after the training interventions.

Materials and methods

Study design and participants

This study was a randomized, controlled trial (RCT), including a three groups parallel 6-months training intervention and a 1-year nonintervention follow-up. Assessments of cognitive performance were performed four times: pretraining, after 3 months, 6 months (posttraining), and at 1-year follow-up. Data collection and training were performed at Geriatrische Klinik St Gallen, Switzerland. The study protocol was approved through the local ethics committee of the canton St Gallen, Switzerland (study number: EKSG 12/092) and registered at Current Controlled Trials ISRCTN70130279. No changes were made to the planned methods after trial commencement. Our reporting in the manuscript adheres to the CONSORT 2010 guidelines.[31]

Participants were recruited through a newspaper article, a local seniors organization,[32] senior residence facilities, primary-care physicians, and via the websites of the city's geriatric hospital[33] and the department of sports of the canton St Gallen.[34] Interested persons were invited to an information event. We included male and female participants because both sexes are similarly affected by age-related cognitive decline.[1] For eligibility, participants had to be older than 70 years, live independently, or at senior residence facilities, and had to sign the informed consent. Residents of retirement homes classified as 0, 1, or 2 within the Swiss classification system for health care requirements (BESA-levels, German abbreviation for Bewohner-Einstufungs- und Abrechnungs-System) could enroll in the study. Level 0 means the person does not need care or treatment; levels 1–2 means, the person only needs little care or treatment. Seniors with diagnosed Alzheimer's disease, dementia, recent head injury, or a score <22 points[35] on the Mini Mental Status Examination (MMSE),[36] which indicates cognitive impairment were excluded. Judgment by their primary care physician was required in the case of acute or instable chronic diseases (eg, stroke, diabetes), rapidly progressing or terminal illnesses before accepting a person for participation.

A priori power analysis (G*Power 3.1.3 Software[37]) revealed a sample size of 75 participants in order to achieve 80% power for a three group pretest, 3- and 6-months test design (25 participants per group). The α-level was set at 0.05 and the effect size *f* at 0.3. The randomization scheme was generated with the website Randomization.com,[38] applying block randomization to achieve three groups with a ratio of 1:1:1. Participants were blinded to the expected study outcome, while blinding of the investigators was not possible since they supervised and conducted training and testing sessions.

Training programs

Two 1-hour training sessions per week were performed in groups of five to six participants, under the instruction of two trained postgraduate students. At least 1 day was included between sessions for recovery. Training programs were based on current recommendations for physical fitness and fall prevention for the elderly.[39–41] The three multicomponent programs consisted of 20 minutes aerobic endurance training (either video game dancing, treadmill memory training, or treadmill walking) and complementary strength and balance exercises (20 minutes each). The exercise training principles of progression and overload were applied for every training component,[42] and they were adapted to each participant's abilities such that a moderate to vigorous intensity was achieved.[39] In total, 52 sessions were performed within 6 months (26 weeks), with some participants missing certain sessions due to personal reasons. Sessions 25–32 (4 weeks) were performed individually according to a home exercise plan, due to Christmas holiday and 3-months test sessions. The home exercise plan comprised the same strength and balance exercises as instructed during normal training sessions, but no video game dancing and treadmill memory training. Compliance to the home exercise plan was assessed with a training diary.

Video game dancing (DANCE)

Program DANCE included virtual reality video game dancing as a simultaneous cognitive–physical training (Figure 1A). This training component combines an attention demanding cognitive task with a simultaneous motor coordination aspect. We used two Impact Dance Platforms (Positive Gaming BV, Haarlem, the Netherlands) and created various levels of difficulty in step patterns and frequency with the StepMania Software.[43] Several styles of music were selected to add variety and meet preferences of participants. Participants stood on the one-by-one meter platform, which contained four pressure sensitive areas to detect steps forward, backward, to the left, and to the right, respectively. Stepping sequences were cued with arrows appearing on a large screen and had

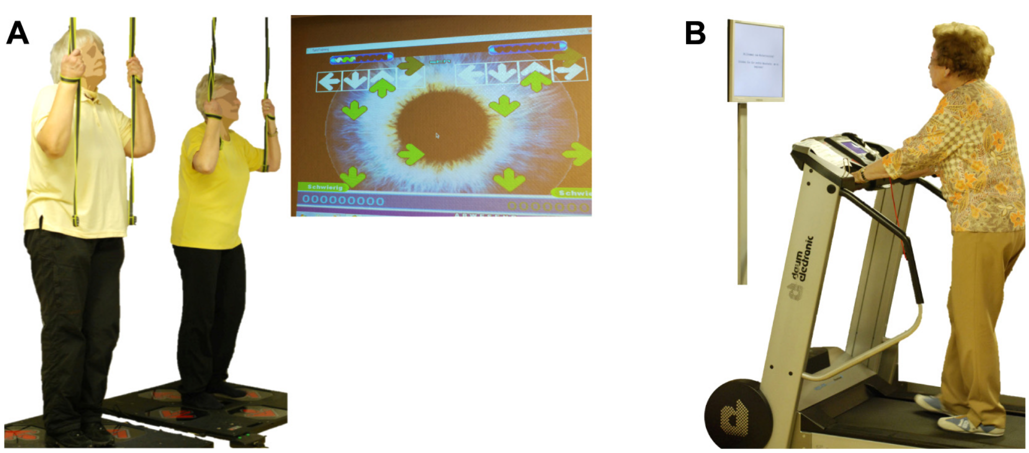

Figure 1 Simultaneous cognitive–physical training components: video game dancing (**A**) and treadmill memory training (**B**). In (**A**) two participants perform steps on a pressure sensitive platform to the rhythm of the music. Step timing and direction is cued with arrows on a screen. In (**B**) a participant is walking on a treadmill while performing verbal memory exercises presented on a computer screen.

to be performed exactly when an arrow reached a highlighted area on the screen in order to achieve best scores in the game. Participants were holding on to ropes for security reasons. Training difficulty was adapted to each individual's coordination ability and was increased progressively.

Treadmill memory training (MEMORY)

Program MEMORY comprised treadmill walking with verbal memory exercise as a simultaneous cognitive–physical training (Figure 1B). Verbal memory training consisted of a computer-based serial position training that was presented on a computer screen in front of the treadmill, with a standard computer mouse as an input device. E-Prime 2.0 Professional software (Psychology Software Tools, Pittsburgh, PA, USA) was used to program the training. Participants were asked to memorize the correct sequence of 3–20 words lighting up one after the other for 3 seconds on the computer screen. Thereafter, a distraction task was followed where participants had to define if three presented words had a meaning or not. Then, the initially memorized words were presented again, either in the same or another sequence, and participants had to decide if the sequence remained the same or not, by pressing the mouse button. The initial level for this training was set at a sequence of three words and was extended by one word as soon as the participants reached 80% of correct answers within the level. Treadmill speed and inclination were set individually for each participant, such that a subjective rate of perceived exertion of five to seven points on the ten-point Borg scale was reached as recommended by the American College of Sports Medicine (ACSM) position stand on exercise with older adults.[39]

Treadmill walking (PHYS)

Program PHYS included aerobic treadmill walking without an additional cognitive task and acted as a reference group with exclusively physical training components. Participants were walking or running at a constant pace. Treadmill speed and inclination were set individually for each participant, such that a subjective rate of perceived exertion of five to seven points on the ten-point Borg scale was reached.[39]

Complementary strength and balance exercises

In addition to one of the three different aerobic training components described earlier, muscular strength and balance exercises complemented each program (Figure 2). Four to five strength exercises for lower and upper extremities and trunk stabilization were performed using own body weight, resistive rubber bands, and weight vests of maximally 10 kg

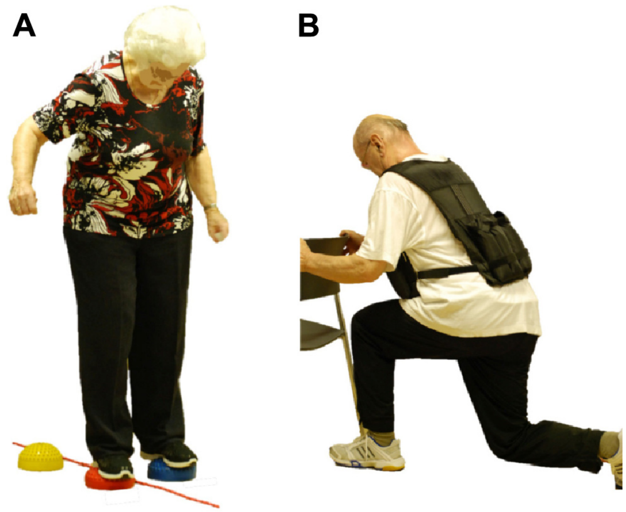

Figure 2 Examples of complementary balance (**A**) and strength (**B**) exercises.
Notes: The participant in (**A**) tries to maintain balance while stepping from one object to the next (objects are soft rubber "stones" and a skipping rope) and (**B**) shows a participant performing split leg squats wearing a weight vest.

(1–3 sets, with 8–12 repetitions, at slow to fast movement speed). Number of sets and repetitions were adapted individually for each participant, such that a subjective rate of perceived exertion of five to seven points on the ten-point Borg scale was reached.[39] Balance training consisted of different exercises including two- and single-leg stance variations, either on the floor or on various types of instable surfaces (eg, foam and air pads, ropes, etc).[44] Exercise level, volume, and intensity were chosen according to the participants' individual abilities and increased progressively.

Measurements

Cognitive tasks (primary outcome)

Cognitive performance was measured by applying a test battery including nine "paper-and-pencil" tasks to assess transfer to different cognitive domains. Four of these tests were repeated at 1-year follow-up, while the other tests were excluded to reduce test time for participants. *Executive function* was measured with the Trail Making Test Part B (TMT-B),[45] *working memory* was assessed with the Executive Control Task,[46] and *long-term visual memory* was tested with three different parallel versions of the Paired-Associates Learning task;[46] furthermore, *long-term verbal memory* was assessed with the German version[47] of the Logical Memory subtest (Story Recall) from the Wechsler Memory Scale-Revised (WMS-R),[48] whereby only one of two different stories from the original test was presented (story A) and no delayed recall after 30 minutes was performed; moreover, *short-term verbal memory* was measured with the Digit Forward and Backward

Tasks from WMS-R,[48] *attention* was tested with three different parallel versions of the Age Concentration Tests A and B[49] (as an adaptation to the original test, we calculated "number of correct figures" divided by "time" as the test result); and finally, *information processing* speed was assessed with the Trail Making Test Part A (TMT-A)[45] and the Digit Symbol Substitution Task (DSST) from Wechsler Adult Intelligence Scale-Revised (WAIS-R).[50]

Training enjoyment (secondary outcome)

Overall training enjoyment was assessed at 6-months test using the German eight-item version of the Physical Activity Enjoyment Scale (PACES).[51,52] The average score of the eight items was used for statistical analysis. Additionally, we asked participants specifically about their enjoyment of the balance and the strength training, as well as the video game dancing, the treadmill memory training, or the treadmill walking. Thereby, we used the same scoring system from one to seven points (least to most enjoyment) as in the PACES. We assumed that training with cognitive elements would be enjoyed more than treadmill walking and that video game dancing would be enjoyed more than treadmill memory training.[53]

Statistical analyses

Group differences in the baseline demographic and performance data were compared with one-way analysis of variance (ANOVA). Multiple regression analysis with planned comparisons, including orthogonal contrast and polynomial trend coding, were applied to investigate training effects on the cognitive test battery for the 6-months training period. We produced contrast coding variables based on the hypotheses. The first contrast was set to compare the two combined cognitive–physical training groups with PHYS. The second contrast compared the two cognitive–physical training groups (DANCE versus MEMORY). According to the study design, comprising three time points of measurement, we created polynomial trend coding variables to assess the linear and quadratic trend. Effect code variables were produced for each group's individuals to account for subject effects. Repeated measures ANOVA with Bonferroni correction was applied for post hoc comparisons from pretest to 3-months test and from 3- to 6-months tests (P=0.025 for two comparisons). Repeated measures of ANOVA were also used to assess differences between 6-months test and 1-year follow-up. Missing values from participants who completed the full 6-months trial but missed single test items due to health constraints or social obligations were replaced by the group mean value at the respective time point of measurement. One-way ANOVA with planned contrasts was performed to compare group differences in the training enjoyment questionnaire. Statistical calculations were performed with IBM SPSS Statistics software for Macintosh, version 22.0 (IBM Corp., Armonk, NY, USA) with a significance level of α=0.05. Effect sizes, represented as R^2-change in the multiple regression analysis, were considered as small for R^2-change =0.01, medium for R^2-change =0.06 and large for R^2-change =0.14 and above; effect size r from one-way ANOVA, was defined as small at r=0.10, medium at r=0.30, and large at r=0.50 and above.[54]

Results

Out of 89 participants initially enrolled, 71 participants completed the 6-months training intervention (20.2% attrition) and were included in the analysis of the outcomes derived at pretest, 3- and 6-months tests. Time points and reasons for dropouts are presented in Figure 3. Dropouts were equally distributed between groups, and therefore, the final analyses were performed only in individuals who completed the 6-months intervention. Forty-seven participants were available for the 1-year follow-up test session and were included in the analysis of these outcomes. The following missing values from persons who completed the 6-months training were replaced by the group mean value: at pretest, three persons from DANCE and two persons from MEMORY missed TMT A and B, one person from DANCE missed four other items, and one person from PHYS missed seven test items; at 3-months test, one person from MEMORY missed all nine tests (this person did not miss any pretests). No missing values were evident at 6 months and follow-up tests. One cognitive task, the Digit Backward Task, was not analyzed because some participants applied a strategy that defeated the idea of the test. Participants' recruitment lasted from August 2012 until the end of September 2012, when pretests were performed. The training intervention lasted from October 2012 until the end of March 2013, with 3-months test at the beginning of January 2013 and 6-months test at the beginning of April 2013. One year later, in April 2014, follow-up test was performed. Table 1 shows baseline demographic characteristics and training compliance of the three intervention groups. Baseline cognitive performance data did not show significant differences between intervention groups for any of the nine cognitive transfer tests (TMT-A P=0.351; TMT-B P=0.334; Executive Control P=0.652; Paired Associates P=0.156; Story Recall P=0.655; Digit Forward P=0.458; Age Concentration A

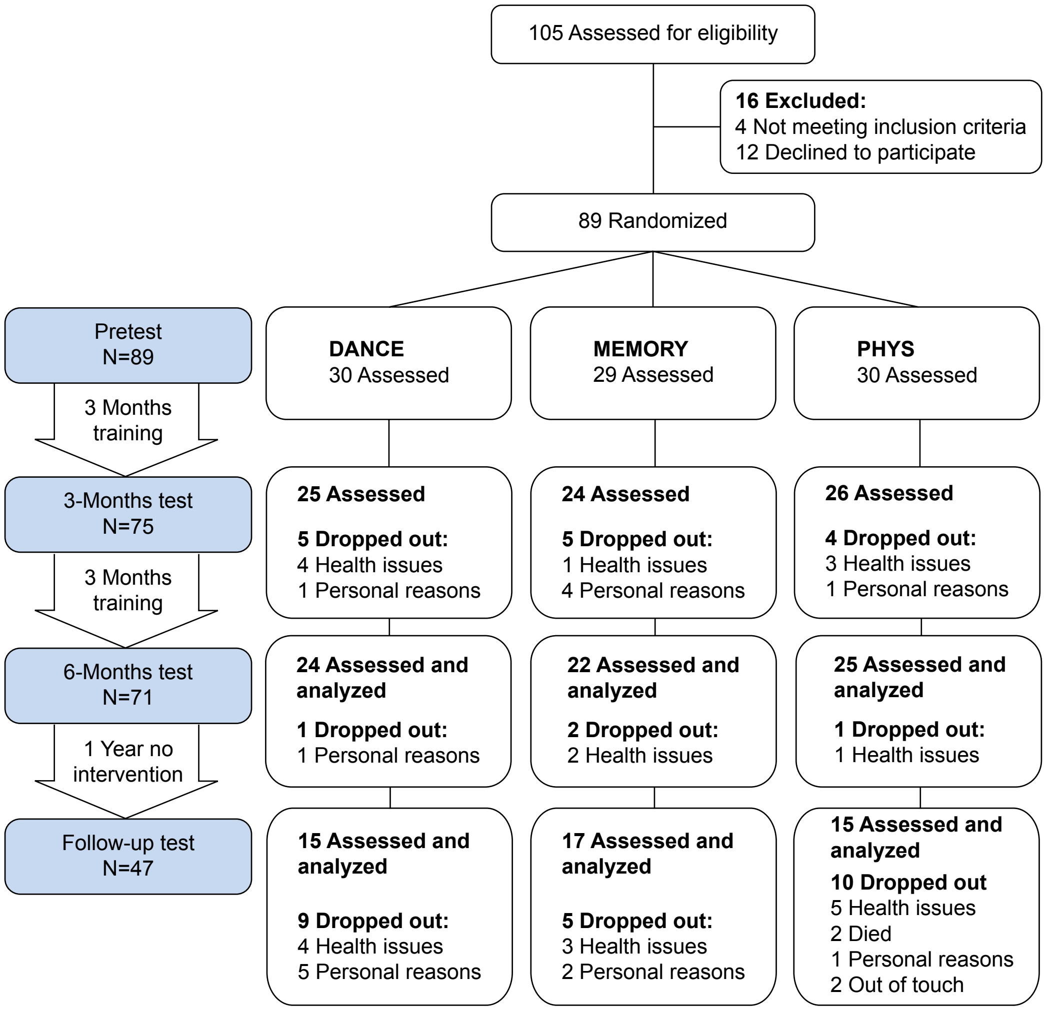

Figure 3 Trial design and participants' flow.

Notes: Participants were randomly assigned to one of two simultaneous cognitive–physical training groups (DANCE and MEMORY) or an exclusively physical multicomponent training group (PHYS) and were trained over 6 months twice weekly for 1 hour. Nine cognitive tests were assessed at pretest, 3-months test, and 6-months test. Four tests were repeated at 1-year follow-up.

Abbreviations: DANCE, virtual reality video game dancing; MEMORY, treadmill walking with simultaneous verbal memory training; PHYS, treadmill walking.

P=0.390; Age Concentration B *P*=0.346; DSST *P*=0.548; all *P*-values two-tailed).

Cognitive tasks

Figures 4 and 5 depict performance development for the nine cognitive tasks. Statistical details of the multiple regression analysis over the first three time points of measurement, including two planned comparisons or contrasts, are provided in Table 2. In eight of nine cognitive tasks, except Digit Forward Task, linear global time effect showed significant performance improvement from pretest to 6-months test in each of the three intervention groups. The analysis of

Table 1 Baseline demographic characteristics and training compliance

Variable	DANCE	MEMORY	PHYS	*P*-value, two tailed
N	24	22	25	
Sex, female	14, 58.3%	16, 72.7%	16, 64.0%	0.602
Age, years	77.3 (6.3)	78.5 (5.1)	80.8 (4.7)	**0.079**^{t}
MMSE, score	28.4 (1.4)	28.3 (1.2)	28.0 (1.7)	0.533
Education, years	13.7 (1.5)	13.9 (2.1)	12.0 (2.1)	**0.002****
Total training compliance (52 sessions)	84.3% (12.7%)	86.1% (9.1%)	87.1% (7.9%)	0.633
Home-training compliance (eight sessions)	79.9% (23.0%)	90.0% (14.8%)	83.5% (18.4%)	0.201

Notes: Data are means (standard deviation in brackets) or numbers. Bold values indicate significance or trend, $^{**}P<0.01$, $^{t}P<0.10$ trend.

Abbreviations: MMSE, Mini Mental State Examination; DANCE, virtual reality video game dancing; MEMORY, treadmill walking with simultaneous verbal memory training; PHYS, treadmill walking.

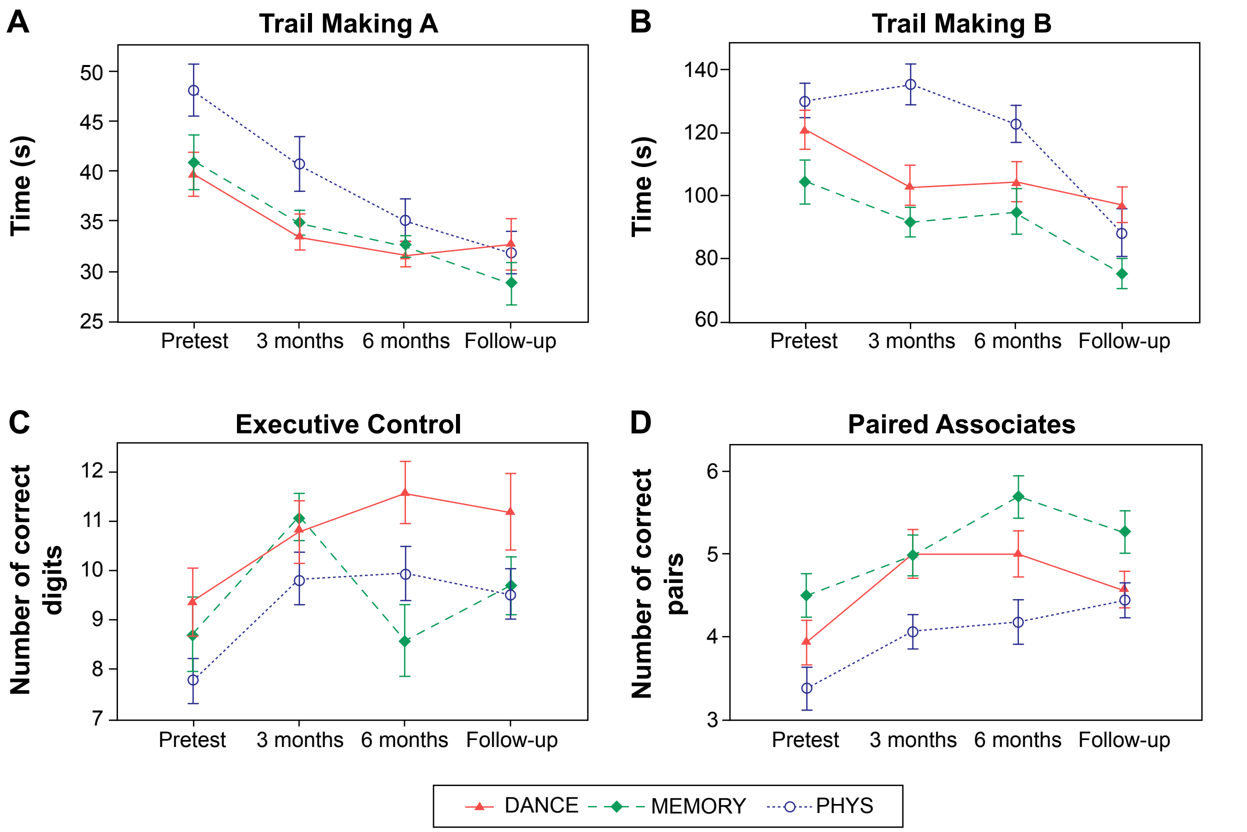

Figure 4 Cognitive performance developments in the four tests that included a 1-year follow-up measurement.
Notes: Significant overall improvements were shown in all tests over the 6-months training period (graphs **A**–**D** all $P<0.05$, one tailed). In Trail Making B (graph **B**), only the two groups with a cognitive training component (DANCE and MEMORY) improved from pretest to 3-months test (trend $P=0.075$, one tailed). In Executive Control (graph **C**), different time courses of adaptation between DANCE and MEMORY were found (trend $P=0.051$, one tailed). From 6-months test to 1-year follow-up test Trail Making B improved significantly (graph **B**, $P=0.015$), while performance was maintained in the three other tests (graphs **A**, **C**, and **D**). Error bars indicate ± standard error of the mean.
Abbreviations: DANCE, virtual reality video game dancing; MEMORY, treadmill walking with simultaneous verbal memory training; PHYS, treadmill walking.

performance maintenance from 6 months to follow-up test is shown in Table 3. Performance remained unchanged until 1-year follow-up test in three cognitive tasks and increased significantly in TMT-B.

The first contrast in the multiple regression analysis tested if the two simultaneous cognitive–physical interventions performed better compared to PHYS. Thereby no significant time×intervention interaction was found. Additional post hoc comparison for performance development in the TMT-B from pretest to 3-months test showed a small to moderate effect with a trend to significance for the time×intervention interaction between DANCE/MEMORY versus PHYS: the two groups with a cognitive training component reduced their time to complete the task, while PHYS was performing slower ($F[2, 68]=1.95$, trend $P=0.075$ [one tailed for directional hypothesis], $r=0.17$). No other trend or significant time×intervention interaction was found for post hoc comparisons of the two separate 3-months training periods (data are not presented).

The second contrast tested differences between the two cognitive–physical interventions. There was a trend to a significant linear time×intervention interaction between DANCE and MEMORY in the Executive Control Task from pretest to 6-months test, reflecting different time courses of adaptation: DANCE improved continuously, while MEMORY showed an improvement over the first 3 months and a decrease of performance, back to baseline level, after the second 3 months of training ($F[1, 136]=2.71$, trend $P=0.051$ [one tailed for directional hypothesis], R^2-change $=0.006$). Additional post hoc comparison of the development in the Executive Control Task from 3-months to 6-months tests revealed a significant time×intervention interaction with a small to moderate effect, also reflecting the aforementioned improvement for DANCE and the decline in MEMORY ($F[2, 68]=3.20$, $P=0.024$ [one tailed for directional hypothesis], $r=0.21$).

Training enjoyment

Training enjoyment was measured at 6-months test in the 71 participants who completed the 6-months training. Results are presented in Figure 6. One-way ANOVA and planned contrasts did not show significant group differences for overall

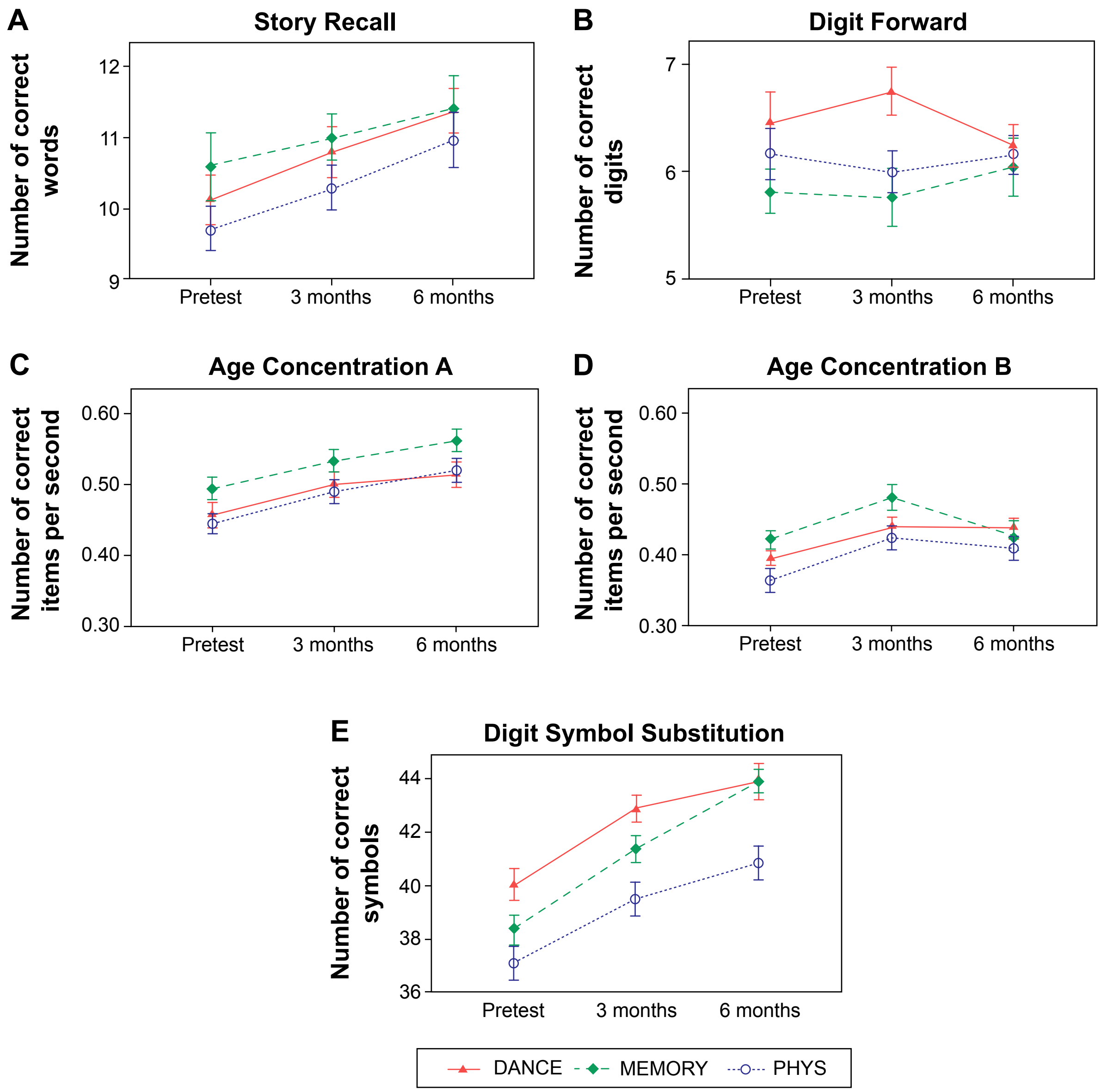

Figure 5 Cognitive performance developments in the five tests that did not include a 1-year follow-up measurement.
Notes: Significant overall improvements were shown in the tests in graphs (**A**, **C**, **D**, and **E**) (all $P<0.05$, one tailed) over the 6-months training period. No improvement was found in Digit Forward (graph **B**). Error bars indicate ± standard error of the mean.
Abbreviations: DANCE, virtual reality video game dancing; MEMORY, treadmill walking with simultaneous verbal memory training; PHYS, treadmill walking.

training enjoyment (PACES, P=0.606), training enjoyment of balance (P=0.979), and strength training (P=0.972). A trend to a significant contrast was found between the enjoyment of the two cognitive–physical training components (video game dancing and treadmill memory training) and the treadmill walking (t[68] =1.503, trend P=0.069 [one tailed for directional hypothesis], r=0.18). Participants seemed to favor the two cognitive–physical components over the treadmill walking.

Discussion

This study aimed to compare two simultaneous cognitive–physical training interventions with an exclusively physical multicomponent training program and to evaluate effects on cognition. The study comprised a 6-months training intervention and a 1-year follow-up. The two main findings were first, that the cognitive–physical programs were partially advantageous to boost performance in two measures of executive function (switching attention and working memory), thereby video game dancing resulted in transfer to an untrained cognitive domain (working memory); and second, that cognitive performance, including executive functions, long-term visual memory (episodic memory), and processing speed, was maintained until 1-year follow-up. These findings are important since executive functions, episodic memory, and processing speed are particularly affected by aging-related decline.[55] Therefore, we suggest that simultaneous cognitive–physical

Table 2 Multiple regression for the linear global time effect (from pretest to 3- and 6-months tests, N=71) and the interaction between orthogonal contrasts and time effect for the cognitive test battery

Dependent variable (cognitive domain)	Predictor	*b*	95% CI		SE *b*	*β*	*P* one tailed	R^2-change
Trail Making Part A (information processing speed)	ABC	–4.93	–6.81	–3.05	0.95	**–0.22**	**<0.001*****	**0.049**
	AB×C	0.78	–0.53	2.09	0.66	0.05	0.120	0.003
	A×B	0.06	–2.27	2.40	1.18	0.00	0.479	0.000
Trail Making Part B (executive function, shifting)	ABC	–5.57	–11.46	0.32	2.98	**–0.08**	**0.032***	**0.006**
	AB×C	–0.93	–5.03	3.18	2.08	–0.02	0.328	0.000
	A×B	–1.76	–9.07	5.56	3.70	–0.02	0.318	0.000
Executive Control (executive function, working memory)	ABC	0.70	0.14	1.27	0.29	**0.11**	**0.008****	**0.013**
	AB×C	–0.19	–0.58	0.20	0.20	–0.04	0.170	0.002
	A×B	0.58	–0.12	1.28	0.35	**0.08**	**0.051**^{t}	**0.006**
Paired-Associates Learning (long-term visual memory)	ABC	0.51	0.26	0.76	0.13	**0.21**	**<0.001*****	**0.043**
	AB×C	0.05	–0.12	0.23	0.09	0.03	0.272	0.001
	A×B	–0.03	–0.34	0.28	0.16	–0.01	0.426	0.000
Story Recall (long-term verbal memory)	ABC	0.55	0.19	0.92	0.18	**0.13**	**0.002****	**0.017**
	AB×C	–0.04	–0.29	0.22	0.13	–0.01	0.389	0.000
	A×B	0.11	–0.35	0.56	0.23	0.02	0.319	0.000
Digit Forward (short-term verbal memory)	ABC	0.00	–0.23	0.23	0.12	0.00	0.493	0.000
	AB×C	0.00	–0.16	0.16	0.08	0.00	0.487	0.000
	A×B	–0.11	–0.39	0.18	0.14	–0.04	0.225	0.002
Age Concentration Test A (concentration, attention)	ABC	0.03	0.02	0.05	0.01	**0.20**	**<0.001*****	**0.040**
	AB×C	0.00	–0.01	0.01	0.01	–0.02	0.366	0.000
	A×B	0.00	–0.02	0.02	0.01	–0.01	0.407	0.000
Age Concentration Test B (concentration, attention)	ABC	0.01	0.00	0.03	0.01	**0.08**	**0.036***	**0.007**
	AB×C	0.00	–0.01	0.01	0.01	–0.01	0.433	0.000
	A×B	0.01	–0.01	0.03	0.01	0.05	0.140	0.002
Digit Symbol Substitution (information processing speed)	ABC	2.20	1.62	2.77	0.29	**0.18**	**<0.001*****	**0.033**
	AB×C	0.16	–0.24	0.56	0.20	0.02	0.216	0.000
	A×B	–0.44	–1.15	0.27	0.36	–0.03	0.113	–0.001

Notes: ABC, linear global time effect; AB×C, linear time×intervention interaction DANCE/MEMORY versus PHYS; A×B, linear time×intervention interaction DANCE versus MEMORY. A, DANCE; B, MEMORY; C, PHYS. Bold values indicate significance or trend, **P*<0.05, ***P*<0.01, ****P*<0.001, ^{t}*P*<0.10 trend.
Abbreviations: DANCE, virtual reality video game dancing; MEMORY, treadmill walking with simultaneous verbal memory training; PHYS, treadmill walking; CI, confidence interval; SE, standard error of the mean.

training should be integrated in training programs aiming to improve cognition in the elderly.

Does simultaneous cognitive–physical training boost cognitive performance?

We found one indication in our results that supported the hypothesis that the simultaneous cognitive–physical programs (DANCE, MEMORY) had advantages over an exclusively physical intervention (PHYS) in terms of cognitive adaptations. Both cognitive–physical interventions showed larger improvements in the TMT-B compared to PHYS within the initial 3-months training period (Figure 4B). This result showed a trend to statistical significance but seems worth mentioning due to the small to moderate effect size.

Table 3 Repeated measures ANOVA from 6-months test to follow-up test, N=47

Dependent variable (cognitive domain)	Effect	*F*(2, 44)	*P* two tailed	*r*
Trail Making Part A (information processing speed)	Time	0.104	0.748	0.05
	Time×intervention	0.664	0.520	0.12
Trail Making Part B (executive function, shifting)	Time	6.444	**0.015***	**0.36**
	Time×intervention	0.372	0.691	0.09
Executive Control (executive function, working memory)	Time	0.110	0.741	0.05
	Time×intervention	1.086	0.346	0.16
Paired-Associates Learning (long-term visual memory)	Time	1.133	0.293	0.16
	Time×intervention	0.216	0.807	0.07

Notes: **P*<0.05. Bold values indicate significance or trend.
Abbreviation: ANOVA, analysis of variance.

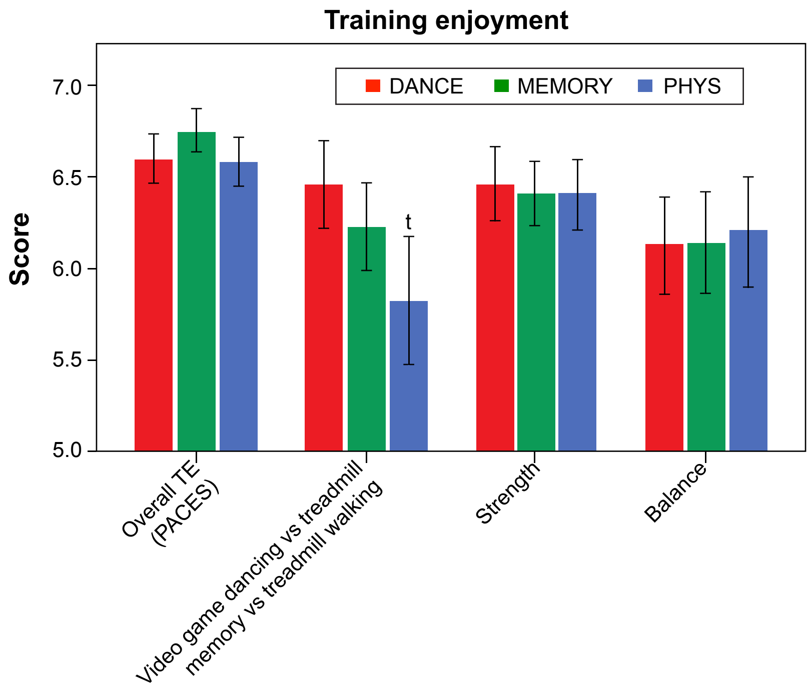

Figure 6 Comparison of training enjoyment in the three interventions.

Notes: No group differences were shown for overall training enjoyment (PACES), strength, and balance training (all $P>0.05$). The two cognitive–physical training components (video game dancing and treadmill memory) tended to be enjoyed more than treadmill walking (trend $P=0.069$, one tailed). Scores system is from one to seven points (least to maximal enjoyment), $^{t}P<0.10$ trend, error bars indicate ± standard error of the mean.

Abbreviations: PACES, Physical Activity Enjoyment Scale; TE, training enjoyment; DANCE, virtual reality video game dancing; MEMORY, treadmill walking with simultaneous verbal memory training; PHYS, treadmill walking.

The TMT-B reflects the ability of shifting attention, which is a dimension of executive function. This ability might have been trained through the simultaneous performance of cognitive and physical activities in DANCE and MEMORY in the way that attention had to be shifted continuously between the two activities. The dual-task situation in the treadmill memory training possibly had some impact on cognitive shifting ability because treadmill walking itself required a certain amount of attention from the elderly participants to be executed safely. A similar result related to cognitive shifting was demonstrated in an investigation that compared effects on cognition after contemporary dancing, Tai Chi, or balance training.[56] Thereby, only contemporary dancing, which can be regarded as a modality of simultaneous cognitive–physical activity, had an effect on cognition and particularly on switching attention as assessed with the Rule Shift Cards Sorting Test.[57] Interestingly, a recent extensive investigation with 182 participants by van het Reve and de Bruin did not show this additional effect on shifting attention after 3 months of sequential cognitive and physical training compared to exclusively physical training (strength and balance exercises).[58] This observation supports the benefits from simultaneously performed cognitive–physical training over sequential cognitive and physical training programs. In our study, participants of PHYS had about 2 years less school education compared to the other groups despite randomization. However, we would argue that this difference had no influence on the development of cognitive outcomes, since baseline cognitive measures and MMSE scores were not statistically different. Furthermore, adaptation patterns were similar in PHYS compared to the other groups in several cognitive outcomes. We conclude that additional cognitive functions, particularly switching attention, are promoted by the dual-task situation in simultaneous cognitive–physical programs and further research is warranted to substantiate or refute this assumption.

The expected differential adaptation patterns from DANCE versus MEMORY were confirmed in the results of the Executive Control Task (Figure 4C), which reflects working memory as another dimension of the executive functions: different time courses of adaptation from pretest, to 3-months, and 6-months tests for DANCE versus MEMORY were found, with superior performance in DANCE after 6-months training. This result was supported by a significant time×intervention interaction with small to moderate effect size in the specific analysis of the second 3-months training period. Within this period DANCE improved, whereas MEMORY deteriorated and PHYS remained unchanged.

Our finding confirms the previously noted importance of applying longer training durations (6 months or longer) to assess cognitive adaptation patterns and to achieve larger training gains from physical interventions.[3,8,59] More importantly, the result represents an adaptation from video game dancing in an untrained cognitive domain (working memory) or a so-called transfer effect. Previous studies on combined cognitive–physical training failed to produce cognitive transfer effects but reported training specific adaptations: for instance, Theill et al[27] demonstrated performance gains in the Executive Control Task after simultaneous cognitive–physical and single cognitive training, which both contained specific working memory exercises. Similarly, van het Reve and de Bruin[58] reported a training specific adaptation after a 3-months computerized divided attention training, which was contained in a sequential cognitive–physical program. In summary, the present study provides first indications that simultaneous cognitive–physical training boosts particular executive functions (shifting attention and working memory) depending on the duration of the intervention, and that the video game dancing leads to cognitive transfer in working memory. However, further investigations are necessary to substantiate this finding. Improvements of executive functions in seniors are clinically important because they are critical for the regulation of gait, are related to fall risk,[60] and are prone to aging-related decline in general.[55]

Are cognitive training effects maintained after cessation of the training intervention?

Training gains were preserved in our study in three out of four follow-up tests over 1 year without any further training intervention being applied. Surprisingly, performance kept increasing in the TMT-B from 6-months test to follow-up test in all groups, which may reflect a delayed response to the intervention. We did not systematically assess the amount of training that participants might have taken up individually after cessation of the intervention. Therefore, we cannot estimate a possible effect of additional individual training on cognitive measures at follow-up. Maintenance of cognitive performance was reported previously after different kinds of training interventions. For instance, a 1-year follow-up cognitive assessment after 6 months of either indoor cycling or stretching and coordination training demonstrated maintenance of selective attention (d2 test) and episodic memory learning.[61] However, only the subgroup with a high level of cardiovascular fitness, measured at follow-up, was able to preserve performance in episodic memory recognition, while the low-fit subgroup deteriorated from postintervention to 1-year follow-up. This finding indicates the importance of cardiovascular fitness as a mediator to maintain certain cognitive abilities. A 5-year follow-up study also reported sustained effects in a composite "cognitive function" score after sequential cognitive–physical training (effect size d_+=0.75),[62] but no performance maintenance was found after exclusively physical training comprising balance and coordination exercises. This finding stands in contradiction to our own result and may support the necessity of multicomponent physical programs containing aerobic endurance and muscular strength exercises for long-term performance maintenance of cognition. Finally, a meta-analysis including seven studies with exclusively cognitive interventions found persistent cognitive enhancements over different follow-up periods from 3 months up to 5 years.[63] Considering the existing literature and our own results, it may be summarized that long-term cognitive performance maintenance can be evident after both, exclusively cognitive or multicomponent physical training containing aerobic endurance and strength exercises, as well as after sequential or simultaneous cognitive–physical interventions. However, which type of intervention might be superior in this respect needs further investigation.

Can simultaneous cognitive–physical and exclusively physical multicomponent training programs elicit broad cognitive adaptations?

A significant global linear time effect in the regression analyses of eight out of nine cognitive tests was found in this study for all three interventions taken together. Therefore, our results might extend the findings from the majority of interventions and meta-analyses with exclusively physical training demonstrating improvements in different cognitive dimensions.[8–11,64–68] However, due to the lack of a passive control group, to account for learning effects from repeated measurements, we are not able to display training effects exclusively. Nonetheless, based on similar results from the literature, the long intervals of 3 months between test sessions and the application of parallel versions in some of the cognitive tests, we assume that performance improvements can at least partly be accounted for as training effects.

Several neurobiological and physiological mechanisms have been suggested to link physical training with benefits on cognitive performance: these are increased neurogenesis and synaptogenesis in the cortical structure, promotion of cerebral metabolism, alterations of neurotransmitter and neurotrophic factor levels, availability of cerebral oxygen and glucose, and reduced oxidative stress.[69] In particular, the cardiovascular fitness hypothesis has been promoted to relate aerobic fitness and cognition. Thereby, aerobic training was found to affect certain mechanisms, such as cerebral blood flow, brain-derived neurotrophic factor, and cerebral structure, which are also associated with increased cognitive performance.[69] Nevertheless, a meta-analysis by Etnier et al[70] failed to support the relation between aerobic fitness and cognition. The authors argued that aerobic fitness itself might not be sensitive enough to indicate cognitive adaptations from aerobic exercise training, whereby the underlying adaptations of aerobic training might be more sensitive.[70] For instance, the cerebral circulation hypothesis relies on studies that have found elevated oxygen and glucose transport to the brain, leading to improved cognitive performance.[71] Furthermore, the neurotrophic stimulation hypothesis suggests that training-induced enhancement of brain-derived neurotrophic factor stimulates neurogenesis and thereby positively affects learning and mental performance.[69] Finally, the neuroadrenergic hypothesis proposed that cardiovascular training promoted neurotransmitter availability, such as noradrenaline, adrenaline, and serotonin, which are thought to be related to memory storage and retrieval.[70,72] As indicated earlier, some recent studies also demonstrated that strength[12] and coordination[11] training induced changes in hemodynamic brain activity or elevated activation of certain brain networks, respectively, which were associated with improved cognition.

The importance of the physical part of a simultaneous cognitive–physical training intervention in older adults was supported by Theill et al[27] who reported improvements in long-term visual memory (Paired-Associates Task) after simultaneous treadmill walking and memory training, but not after exclusively cognitive training. Additionally, two meta-analytic studies pointed out that exclusively cognitive training programs increased performance only on related or training-specific tasks and no cognitive transfer effects were evident.[15,16] This was also confirmed by the recent review from Oei and Patterson[17] who investigated transfer effects in video game training studies. However, some cognitive training studies reported broad improvements from cognitive training, particularly from extended but not from strategy training approaches.[14] Extended practice refers to the training of basic cognitive abilities, such as choice response time or phoneme span, which are used in different cognitive activities. Additionally, a recent meta-analysis by Hindin and Zelinski[13] found similar effect sizes in extended cognitive training compared to aerobic exercise training, although different neurophysiological mechanisms would likely have led to these effects. Nevertheless, it appears that physical and combined cognitive–physical training interventions may be more beneficial than exclusively cognitive training interventions for older adults to enhance a broad range of cognitive abilities. Such training programs should therefore be implemented in the clinical prevention of cognitive impairments, which are widely prevalent in older adults.[1]

Strengths and limitations

Methodological strengths of this study were the comparably large number of participants, the long training period with follow-up measurements, and the broad cognitive testing battery to assess several dimensions of cognition. Some limitations have to be considered as well. First, the specific effects of the two simultaneous training modalities could not be identified exactly because of the combination with the multiple physical components (strength and balance training). However, this was not the focus of this study, since we explicitly aimed at evaluating effects from different multicomponent programs. Second, the conclusions and recommendations from this study are limited to physically and mentally healthy seniors, because following the selection criteria such participants were recruited. Training effects might have been even larger in a population of lower physical and mental status. This assumption is based on the exercise training principle "Initial Values" stating that improvement in the outcome of interest will be greatest in those with lower initial values.[42] Those with lowest levels of fitness theoretically have greatest room for improvement. It seems, therefore, important and warranted to repeat the study design in a more vulnerable population exhibiting impairments in fitness and/or cognitive domains. Further, as mentioned earlier, we did not include a passive control group in the design of the study, which means that we could not exactly differentiate between training effects and learning effects from repeated testing. However, this was not the main focus of the present study. Although participants were blinded to the expected study outcome, blinding of the investigators was not possible since they also supervised and conducted training and testing sessions. This is an additional limitation to this study.

Conclusion

We demonstrated that multicomponent simultaneous cognitive–physical training programs have the potential to boost particular executive functions (including shifting attention and working memory) in healthy older adults compared to an exclusively physical multicomponent program.

Importantly, performance levels in executive functions, long-term visual memory (episodic memory), and processing speed were maintained over 1 year after all three programs. The novel training concepts of simultaneous cognitive–physical activity tended to be enjoyed more by seniors than traditional training and led to training specific as well as to transfer adaptations in cognition. Therefore, we recommend multicomponent simultaneous cognitive–physical training programs to enhance particular executive functions in older adults. Such programs may potentially counteract the large prevalence of cognitive impairments and decline in the elderly, inherently leading to more independence and a better quality of life. Future studies should also investigate the neurological background of cognitive behavioral performance enhancements to shed light on the interconnection between plasticity of cognition, brain function, and brain structure.

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Author contributions

PE, study preparation and conception, participants' recruitment, data acquisition, statistical analysis, data interpretation, drafting manuscript; VS, study conception, conception of cognitive test battery, data interpretation, revising manuscript; MA, study preparation, training instruction, data acquisition, data interpretation, revising manuscript; NT, study conception, conception of serial position training, supporting statistical analysis, data interpretation, revising manuscript; EDB, study conception, data interpretation, revising manuscript. All authors read and approved the final manuscript.

Disclosure

The authors report no conflicts of interest in this work.

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Rough and Tumble Play

Rough and tumble play has been defined as physically vigorous behaviors, such as chase and play fighting, that are accompanied by positive feelings between the players. This play type was first named by anthropologist Karl Groos in his books “Play of Animals” (1898) and “Play of Man” (1901).[1]

Children enjoy engaging in rough and tumble play. As they are wrestling, hitting, and chasing one another, they are laughing and squealing as willing participants and keep returning for more. While adults may be concerned that their play is real fighting or aggression, children are adept at discerning the difference and will indicate if the play has gotten too aggressive and respond accordingly to continue the play.[2] If a child gets hurt, the play pauses for a moment to resolve the issue, and then the play resumes. Children will learn how far they can go in playing rough and discover the boundaries for healthy play.[3] Rough and tumble play allows a child to understand the limits of their own strength and discover what other children will and won’t allow them to do.[4]

There are many social benefits to rough and tumble play. Children discern the give-and-take of appropriate social interactions and learn to read and understand the body language of other children. The social skills of signaling and detecting signals developed through play will be used throughout their lives. They also learn to change roles in their play as at times they are chasing others and then being chased themselves.[5]

Rough and tumble play often requires intense physical exertion that aids cardiovascular health as well as developing motor skills and muscles as they play in chase games or wrestle with one another. These activities especially give boys the opportunity to address their need for power and to physically touch each other while playing. In the spirit of play, children work hard to demonstrate their ability to be competent through rough and tumble play.[6] They may be playing King of the Mountain, pretending to be super heroes, or engaging in mock karate. In time, rough and tumble games expand into more sophisticated games like organized sports, continuing the need to be physically active as they move into adolescence.[7]

School age children spend 17% of their play time as rough and tumble play. The amount of time spent in rough and tumble play peaks during the elementary school years and then declines in middle school. Boys generally engage in physical play more often than girls and choose other boys to play with, while girls will select both boys and girls.[8] Boys enjoy wrestling and holding each other down, while girls prefer chasing games.[9]

From the 1960's through the 1990's, it was thought that aggressive behavior in young children was acquired mainly through observation and imitation of others. Roughhousing was discouraged, because it was thought it would lead to aggressive hostile behavior. Recent research has shown that aggression emerges naturally in children and diminishes as children learn to express themselves appropriately through the social interaction of rough and tumble play.[10]

With the reduction of opportunities for children to engage in free play in today's society, there has been a rise in concerns about the poor socialization of children as a whole.[11] Lack of rough and tumble play hinders the normal give-and-take experience necessary for social mastery and has been linked to poor control of violent impulses later in life. Dr. Stuart Brown studied the play histories of young murderers in Texas and found an absence of rough and tumble play in their childhoods. Rough and tumble play is necessary for the development and maintenance of social awareness, fairness, cooperation, and compassion.[12]

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Rough-and-Tumble Play and the Regulation of Aggression: An Observational Study of Father–Child Play Dyads

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Abstract

Rough-and-tumble play (RTP) is a common form of play between fathers and children. It has been suggested that RTP can contribute to the development of selfregulation. This study addressed the hypothesis that the frequency of father–child RTP is related to the frequency of physically aggressive behavior in early childhood. This relationship was expected to be moderated by the dominance relationship between father and son during play. Eighty-five children between the ages of 2 and 6 years were videotaped during a free-play session with their fathers in their homes and questionnaire data was collected about father–child RTP frequency during the past year. The play dyads were rated for the degree to which the father dominated play interactions. A significant statistical interaction revealed that RTP frequency was associated with higher levels of physical aggression in children whose fathers were less dominant. These results indicate that RTP is indeed related to physical aggression, though this relationship is moderated by the degree to which the father is a dominant playmate.

Keywords: rough-and-tumble play, physical aggression, self-regulation, father
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INTRODUCTION

Physically aggressive behaviors such as hitting, kicking, pushing, and biting are observable as early as 18 months of age [Tremblay et al., 1999, 2004]. Longitudinal data shows that the frequency of physically aggressive behaviors decreases starting at the age of 2–3 years [Bongers et al., 2004; NICHD Early Child Care Research Network, 2004; Tremblay et al., 1999, 2004]. However, for a small but significant group of children, high levels of aggression persist and these children are at risk for chronic psychosocial problems later in life including adult crime, alcoholism, drug abuse, unemployment, divorce, and mental illness [Broidy et al., 2003; Loeber and Hay, 1997; Moffitt et al., 1996; Rutter, 1996]. In addition to these risks to the individual, physically aggressive behavior is often damaging to the victims and the downstream consequences of these events are very costly to society, both financially and socially [Frick, 2001].

Despite recent progress, early prevention programs designed to protect aggressive children from long-term risk of psychopathology have achieved only modest success [Frick, 2001; Lochman and Salekin, 2003]. To date the consensus is that early, multi-component interventions tend to have the greatest impact [Connor et al., 2006; Lochman and Salekin, 2003; Sanders et al., 2000]. Yet, there continues to be a need for research in the factors affecting the development of behavior regulation that could be translated into early interventions and improve long-term outcomes [Carson et al., 1993; Lochman, 2006]. It has been suggested that parent–child rough-and-tumble play (RTP) can contribute to the development of a child's ability to regulate his or her own aggression [Carson et al., 1993; Paquette, 2004; Paquette et al., 2003b; Peterson and Flanders, 2005]. This study investigates the potential role of father–-child RTP in the development of a child's capacity to regulate aggression.

Play and Socialization

It is well known that parent–child physical play is an important component of human socialization [Barth and Parke, 1993; Lindsey et al., 1997; MacDonald, 1993; MacDonald and Parke, 1984; Parke et al., 1988]. Sex differences appear to be the rule in this domain: boys engage in more RTP than their female counterparts in all cultures investigated to date [Pellegrini and Smith, 1998]. Yet, both boys and girls enjoy physical play over other types of play and fathers are the preferred play-mate [Ross and Taylor, 1989].

Fathers appear to socialize their children especially through physical play: father–child physical play is associated with peer competence [Carson and Parke, 1996; Lindsey et al., 1997; MacDonald and Parke, 1984]. Other studies have shown that this form of play is associated with emotion-regulation [Barth and Parke, 1993; Carson and Parke, 1996] and emotion-encoding skills [Carson and Parke, 1996; Parke et al., 1988], both of which are known to be related to peer competence [Field and Walden, 2008; Zeman et al., 2006]. The most popular children are those of fathers who exhibit high levels of physical play with both sons and daughters (3–4 years) and elicit high levels of positive feelings during play sessions [Corr et al., 1995]. Furthermore, children who experience greater difficulty in decoding emotions are less willing to engage in physical play with peers [Lewis and Thomas, 1990]. While the causal mechanisms have not been established, this body of research suggests that fathers can teach their children selfcontrol and sensitivity to others through play [Carson et al., 1993; Paquette et al., 2003a,b; Peterson and Flanders, 2005] and that these skills become important in the schoolyard when peers negotiate social rules among themselves through play [Pellegrini, 1995].

RTP is a specific form of physical play, characterized by aggressive behaviors such as wrestling, grappling, jumping, tumbling, and chasing, in a play context [Pellegrini and Smith, 1998]. The early research on RTP was done on nonhuman animals. The RTP of rats, hamsters, monkeys, and chimpanzees is fairly well-described [Chalmers, 1983; Paquette, 1994; Pellis and Pellis, 1987, 1988] and studies have clearly established links between RTP and frontal-lobe functioning [Burgdorf et al., 2006; Panksepp et al., 2003; Pellis et al., 2005, 2006] and socialization, particularly in primates [Hughes, 1991; Millar, 1968]. Although adults often confuse RTP with genuine aggression [Scott and Panksepp, 2003], research has clearly distinguished these two types of behaviors [Jones, 1972] and demonstrated that they arise from two distinct motivational systems, one associated with affiliation and the other with competition [Panksepp, 1998a; Paquette, 1994; Pellis et al., 2005].

The frequency of father–child RTP peaks late in the preschool years. On average, when children reach 3–4 years of age, RTP accounts for roughly 8% of total parent–child interactions [Pellegrini and Smith, 1998]. Typically, this period is also important in the development of the selfregulatory functions of the frontal lobes [Séguin and Zelazo, 2005;

Zelazo et al., 1997], especially, the ability to regulate aggressive behavior. Thus, RTP is a potentially important context for studying individual differences in father–child relationships and the impact of these differences on the development of aggressive behavior in children. Despite its potential importance, father–child RTP is surprisingly understudied [Panksepp et al., 2003], probably because many adults find it disruptive and dangerous [Panksepp, 1993], though this is true of many aspects of fatherhood.

Dominance in Dyadic Play

Fathers tend to stimulate their children physically, emotionally, and cognitively during play. They also push them to take risks and reach for their physical, cognitive, and emotional limits [Paquette, 2004]. However, using their increased size, strength, and cognitive abilities, fathers can provide a secure environment for these interactions by asserting their authority and setting limits on their children's behavior. These parental behaviors constitute an expression of dominance and are especially important for preschool aged children, whose selfregulation abilities are just starting to emerge, just as it is in the RTP of rat pups [Panksepp, 1998b], chimpanzees [Paquette, 1994], and preadolescent children [Pellegrini and Smith, 1998].

Traditionally, dominance has been defined by animal behaviorists in terms of group social hierarchy [Dunbar, 1988]. Dominance hierarchies emerge as a result of antagonistic dyadic confrontations among individual members of the group [Strayer and Strayer, 1978]. Thus, dominance is achieved through coercive and aggressive confrontation. Defined in this way, dominance is not a common feature of the social life of human adults [Hawley, 1999]. In the human adult literature, social dominance in adults is typically seen as a personality dimension, referring to a coercive or aggressive interpersonal style [Moskowitz, 1993; Mudrack, 1993]. However, dominance in humans may be best defined in terms of a dyadic, affiliative relationship between individuals [Pellegrini et al., 2007], such that within a relationship one individual is more likely to have the upper hand with respect to access to resources or control over circumstances [Hawley, 1999]. Defined in this way, dominance is a highly relevant characteristic of human social behavior, and it is particularly easy to observe in young children [Hawley, 1999].

Children often use play interactions, especially RTP, to negotiate dominance among them [Pellegrini and Smith, 1998]. For example, during RTP, one individual typically has the upper hand, which may involve pinning, holding, pushing, or tickling. A child can assert dominance over a peer by using greater strength or "toughness" to hold the upper hand in RTP [Pellegrini and Smith, 1998]. In specific dyads, one child is more likely to hold this position than the other and stable patterns of dominance and submission within relationships emerge over time [Pellegrini and Smith, 1998]. This kind of physical prowess is typically important to a child's social standing among peers at school [Pellegrini, 1995]. Similar dynamics operate in father–child play dyads as well, as each competes to hold the dominant position over the other. Because fathers are typically bigger and stronger, they typically get to decide whether and how much they allow their children to take the upper hand temporarily, with a behavior known as selfhandicapping [Pellegrini and Smith, 1998]. However, the degree to which a child is allowed to get the upper hand varies from dyad to dyad and this variability may be linked to the development of control over physical aggression in the child. Paquette [2004] proposed that children would learn selfregulatory strategies from RTP interactions in which their father is in control of play. Conversely, if children were allowed to dominate play and impose their will on their fathers, they would not learn social boundaries of their aggressive behavior and, as a result, be less skilled at selfregulating these behaviors over time.

This Study

The aim of this study is to test that hypothesis. Among father–child play dyads in which the father is more dominant, the frequency of RTP interactions should be associated with less aggressive behavior. Among dyads in which the father is less dominant, the frequency of RTP interactions should be associated with more physical aggression. We tested this hypothesis with 85 father–child dyads observed during a free-play session. Observational methods allowed for real-time description of dominance dynamics during play. Boys were expected to engage in more RTP and physical aggression than girls, but the relationship between RTP and aggression is hypothesized to be similar within each gender.

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METHODS

Participants

A nonclinical sample of 85 father–child dyads was initially recruited to participate in the current project. Fathers were solicited to participate in a study of father–child play interactions with notices that were placed at the entrances of local community health centers in the province of Quebec, Canada. Recruitment was also done with ads in cafes and through word of mouth. Table I contains a summary of the characteristics of the sample. All the testing was conducted in French and all participants were either francophone or spoke French as a second language. Children (43 boys and 42 girls) were between the ages of 2 and 6 years (mean = 45.8 months, SD = 12.9 months). This age range was chosen because it corresponds with the period in which parent–child RTP activities are most common [Pellegrini and Smith, 1998]. All participants were treated in accordance with the ethical guidelines of the American Psychological Association's Ethical Principles and Guidelines for the Protection of Human Subjects of Research [American Psychological Association, 2002]. Participants gave their consent to participate in the experiment and were compensated $20.00 for their time.

TABLE I
Characteristics of the Sample

Two biological parents	87.50%
Sex ratio (boys/girls)	43/42
Average age (years)	33.6 (7.9)
of father (SD), range	20–55
Average age (years)	31.3 (7.2)
of mother (SD), range	17–43
Average age (months)	45.8 (12.9)
of children (SD), range	22–71
Average number of children	1.7 (.8)
(SD), range	40.0%
Average number of years of	14.0 (3.3)
Schooling of father (SD), range	14
Average hours with child	13.98 (6.1)

TABLE I
Characteristics of the Sample

Materials

A digital camcorder was used to record play sessions between the fathers and their children. The Observer Video-Pro [Noldus et al., 2000], a specialized software for observational coding, was used to code the videos, from which the dominance measures were obtained. A series of questionnaires was used to assess the frequency and quality of father–child play activities, the behavior of the child, and the father's parenting practices.

Measures

Play frequency

The "Pére-En-Jeux" questionnaire asks fathers to evaluate the frequency of various parenting behaviors with the following response options: "never," "sometimes," "regularly," "often," or "very often" ["jamais", "à l'occasion", "réguliérement", "souvent", or "trés souvent"]. The item pertaining to RTP frequency was: "How often do you play fight with your child?" [Avez-vous l'occasion de jouer au jeu de bataille avec votre enfant?]. The item pertaining to play in general was: "How frequently do you play with your child" [À quelle fréquence jouez-vous avec lui?]. Previous research with this questionnaire has shown that the data retrieved by the "Pére-En-Jeux" questionnaire is highly correlated with observational data [Paquette et al., 2003a]. Standardized scores for the continuous variables were used for the analyses.

Physical aggression

Physical aggression was assessed with the Behavior Questionnaire [Tremblay et al., 1992]. Fathers were asked to report on the frequency of physical aggression by responding "never or not true," "sometimes or somewhat true," "often or very true," or "don't know" to ten items, such as: "kicks others," "physically attacks others," "hits or punches others," and "gets into fights." The internal consistency for the scale was adequate (father: $\alpha = .84$). Standardized scores for the continuous variables were used for the analyses.

Father dominance

The "Play Regulation Coding Scheme" (PRCS) was designed to describe the dominance relationship between child and father during play. It was adapted from a similar scheme designed to describe the quality of parent–child interactions [Kerns and Barth, 1995]. Every 10 sec during active play bouts, father–child dyads were given a "dominance" score based on behaviors and communications reflecting the degree to which the father controlled the flow of play or held the dominant position in relation to the child during that time frame. High scores were given to dyads in which the father controlled play (e.g. picking up or pinning a child in wrestling, being the aggressor in tickling or chasing). Lower scores were given to dyads in which the child had greater input into the flow of play (e.g. "daddy, it's *my* turn to tickle *you*" or "let's play the running game, we'll start from here") or the father allowed the child to take the upper hand (e.g. the child becomes the aggressor in tickling). Medium scores were given to dyads that shared the control of play circumstances and the dominant position (e.g. taking turns having the upper hand). The style of communication was also considered in this measure, with more directive communications (e.g. "Johnny, run over here and tackle me!") getting a higher score than requests (e.g. "do you want to play horsey?"). Scores ranged from 0 to 4, where 0 =passive or submissive, 2 =shared, 4 =dominating or in charge, and 1 and 3 were midpoints between these anchors (mean =3.08; SD =.55). A dominance score was computed for each dyad based on the mean of the ratings through the play episode.

It is important to note that the dyad's level of dominance was assessed every 10 sec during all types of play interactions (e.g. RTP, nonphysical play, etc.). While RTP was widely observed in this sample, not all participants engaged in this form of play during the observation period. Therefore, the dominance scores are not an assessment of dominance during RTP, but a mean score of dominance ratings during play in general. We are working from the assumption that the dominance dynamics during play in general apply to the RTP interactions about which the father reported on the "Pére-En-Jeux" RTP frequency questionnaire item.

Socio-demographics

Basic socio-demographic characteristics of the families in the sample included the following:

a. *Age*: Fathers were asked to indicate their age in years and the age of their children in months.
b. *Family Income*: Fathers were asked to estimate the total annual income for their families. They had to choose from a series of response options ranging from "less than $10,000" to "more than $80,000."
c. *Education*: Fathers were asked to indicate their last year of schooling completed.
d. *Time with child*: Fathers were asked to indicate how much time they spent alone with the target child, in hours during the week and on the weekend. A sum of the two reports was calculated and then standardized for use in the analyses.

Procedure

Data collection took place in two stages. During the first in-home visit, after a period spent familiarizing the father–child dyad with the male assistant and the camera that had been set up in a corner of the living room, the dyad was filmed for a seven-minute free-play period with no toys. After the play session, fathers completed questionnaires on their socio-economic characteristics, and the "Pére-en-jeux" questionnaire. During the second visit, six months later, fathers completed a questionnaire on their child's social behaviors.

Research assistants visited the participating families in the homes. In a free-play context with no toys, the fathers were given the following directions: "Play the way you usually do with your child." To ensure the ecological validity of the observations, the dyads were given ample time to adjust to the novel situation. The video camera was small and set up on a tripod as far from the dyad as possible. The research assistant was told to be as inconspicuous as possible during the observation. The fact that all but six participating dyads engaged in some play during the observation period supports the ecological validity as children tend not to play if they are uncomfortable or in novel surroundings [Millar, 1968]. The dyads were filmed for 7 min of free play and the fathers were then asked to fill out the series of questionnaires. Only two fathers who were observed during play did not fill out the questionnaires. Once the visit was completed, the videos were coded using the PRCS in the "The Observer Video-Pro" software package.

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RESULTS

Verifications of the assumptions of normality, linearity, and homoscedasticity of residuals led to transformations of some variables to reduce skewness and reduce the number of outliers. Values that were three standard deviations from the mean were considered outliers. Two outliers were detected on the physical aggression measure and these were recoded to the next highest values. Logarithmic transformations were used on the measures of physical aggression and time spent with child. Standardized scores for the continuous variables were used for analyses.

Validation of the Dominance Measure

Two research assistants coded the videos using the PRCS. They each coded half of the videos independently and in addition to another 20%, which they both coded for the purposes of evaluating inter-rater reliability. We used an intraclass correlation between the two sets of codes for the overlapping videos to calculate inter-rater reliability. Intraclass correlations are equivalent to weighed κ statistics, a common index of inter-rater reliability [Fleiss and Cohen, 1973]. The inter-rater reliability was adequate (intraclass correlation =.77, P<.01). In cases where there was disagreement between the coders, an average of their two ratings was used in the final data set. Based on the model outlined above, a father who is less dominant during RTP was expected to have a child with greater physical aggression than a more dominant father. These associations were examined with Pearson correlations (N =77). The father dominance score was significantly negatively associated with physical aggression (r =−.35, P<.01) and RTP frequency (r =−.45, P<.01).

Frequency of Father–Child RTP

The mean level of father–child RTP was 2.53 (SD =1.21). According to the father reports on the questionnaire, boys (mean =3.05; SD =1.32) engaged in father–child RTP significantly more frequently than girls (mean =2.02; SD =.84) t(83) =4.23, P<.01. As a result, sex was included in the initial regression model. Data from only 77 of the 85 children were used in further analyses, because six dyads failed to initiate a single play bout of 10 sec or longer and two fathers did not answer the RTP frequency question. T-tests show that these eight dyads did not significantly differ from those included in the analyses on physical aggression child age, father age, father education, and family income.

Relations Among Variables

Table II illustrates the correlations among the principal variables used in this study. Of note, father dominance was significantly negatively associated with RTP frequency, physical aggression, and age of the child, indicating that children with less dominating fathers tended to engage in more RTP with their fathers, were more aggressive in every-day life, and were older. RTP frequency was associated with physical aggression. This correlation suggests that aggressive children engage in more RTP with their fathers. However, we expect father dominance to moderate this effect. It is worth noting that RTP frequency was not associated with father age or socio-economic background, suggesting that RTP is common to all kinds of households.

TABLE II

Correlations Among Principal Variables in the Model and Key Demographics

	Father dominance	RTP frequency	Play frequency	Physical aggression	Child age	Fath[er] ag[e]
RTP frequency	***−.46	–				
Play frequency	.05	*.20	–			
Physical aggression	***−.34	**.28	−.02	–		
Child age	**−.26	.10	**−.26	.01	–	
Father age	.00	−.12	−.01	−.08	***.29	–
Father education	−.08	.02	.1*	.01	−.09	*** [illegible]
Family income	−.11	.12	***.29	−.04	−.07	.1[illegible]
Time with	.10	−.05	−.02	−.24**	−.18	−.[illegible]

TABLE II
Correlations Among Principal Variables in the Model and Key Demographics

RTP, Dominance, and Physical Aggression

A sequential multiple regression was performed with physical aggression as the dependent variable and RTP frequency, father dominance, overall time spent with the child, and sex as independent variables.

In a first regression model, we examined if the expected relations would be moderated by child sex. Step 1 included the overall amount of time the father spent with his child. Step 2 included RTP frequency, father dominance, and sex. Step 3 included the interactions between RTP frequency and dominance, RTP frequency and sex, and father dominance and sex. Step 4 included the three-way interaction between RTP frequency, dominance, and sex of the child.

The three-way interaction was not significant, nor were either of the two-way interactions involving sex, so a second model was run without sex (see Table III). Three significant predictors of physical aggression were detected in this reduced model. The main effect of time spent with child was significant $\beta = -.22$, $t(76) = -2.11$, $P = .04$, indicating that the more time the father spent with his child, the less aggressive his child was. The main effect of father dominance was significant $\beta = -.27$, $t(76) = -2.26$, $P = .03$, indicating that the more dominant the father was during play interactions, the less aggressive the child was in general. Finally, the interaction between RTP frequency and father dominance was also significant $\beta = .29$, $t(76) = 2.70$, $P = .01$.

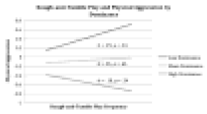
TABLE III

Summary of Sequential Regression Analysis for Variables Predicting Physical Aggression (N=77)

	Variables	R^2	B	SE B	β	P
Step 1		.05				
	Time with child		−.23	.12	−.22	.05
Step 2		.17				
	Time with child		−.20	.11	−.20	.07
	RTP frequency		.08	.12	.08	.51
	Dominance		−.30	.12	−.30	.02
Step 3		.25				
	Time with child		−.22	.11	−.22	.04
	RTP frequency		.05	.12	.05	.65
	Dominance		−.27	.12	−.26	.03
	RTP frequency × dominance		.23	.09	.29	.01

TABLE III
Summary of Sequential Regression Analysis for Variables Predicting Physical Aggression (N=77)

The interaction was decomposed using a procedure outlined by Holmbeck [2002], following the recommendations of Aiken and West [1991]. The results suggest that, among the less dominant fathers, more frequent RTP was associated with higher levels of physical aggression in their children ($t(73)=2.06$, $P = .04$). Figure 1 illustrates the interaction effect graphically.



[Fig. 1](#)
The interaction of father dominance and father–child RTP frequency in predicting child physical aggression.

To test whether the relation of RTP to aggression was specific to RTP and not accounted for by a more general tendency of the father to play with the child, we added both the general play main effect and the general play by dominance interaction into the model. Neither effect was significant, suggesting that the central finding reported here is not accounted for by a general play effect.

The age of the children participating in the study ranges from approximately 2 to 6 years and children's capacity for selfcontrol typically changes through this period. As a consequence, the degree to which fathers control play may evolve as well and the importance of dominance in play may vary with the age of the child. To test the hypothesis that child age moderated the relationship between RTP, dominance, and aggression, the reduced model described above was rerun with a main effect of child age, the RTP-by-age and dominance-by-age two-way interactions, and the three-way interaction between RTP, age, and dominance. None of the effects including the age of the child were significant, indicating that the age of the child did not affect the relationship between RTP, dominance, and aggression.

Go to:

DISCUSSION

The main purpose of this study was to determine whether RTP between fathers and their young children is related to the children's ability to regulate physical aggression. It was hypothesized that, among father–child dyads in which a father controls and sets limits during play, the frequency of RTP specifically would be associated with lower levels of physically aggressive behaviors in every-day life. The reverse should be the case among dyads in which fathers are less dominant playmates. We found that, indeed, dominance moderated the relationship between RTP and physical aggression. Children were more aggressive as a function of RTP but only if their fathers were relatively less dominant playmates.

The results of this study were maintained after controlling for several related variables. It has been widely observed that boys tend to be more aggressive [Maccoby and Jacklin, 1974] and engage in more RTP than girls [Pellegrini and Smith, 1998]. However, the results indicate that sex did not moderate the relationship between RTP and aggression, even though boys engaged in more RTP than girls. Complementary analyses showed that the age of the child and the overall amount of time the father spent with his child did not influence the findings. In addition, the observed relationship between RTP, dominance and aggression, was not accounted for by play in general. Overall, these results indicate that RTP activities can indeed be associated with behavior problems, as some adults believe [Panksepp, 1993], though these associations likely arise when fathers are unable to contain and impose limits on play interactions.

The current findings provide partial support for the theoretical models proposed by Paquette [2004] and Peterson and Flanders [2005]. Paquette argues that fathers can help their children learn to better manage their aggressive emotions through controlled confrontations in RTP. Peterson and Flanders [2005] proposed that RTP contributes more broadly to the development of selfregulation as it cultivates a child's identification with others. Because RTP is sustainable only as long as both participants enjoy themselves, children must learn to modulate their actions to maintain their fathers' enjoyment, even in the heat of the moment. These models are consistent with the literature indicating that father–child physical play is related to the child's social competencies with peers [Parke et al., 2002]. Furthermore, the frequency of these interactions peaks in the preschool years [Pellegrini and Smith, 1998], the period of significant change in a child's psychological and behavioral selfregulatory abilities in general [Séguin and Zelazo, 2005; Zelazo et al., 1997].

These findings have promising implications for the study of physical aggression. Physically aggressive behavior in early childhood is a risk factor for the development of chronic psychopathology later in life [Moffitt et al., 1996]. The presence of a father figure in a child's life can protect children from these risks [Amato and Rezac, 1994], though as this study confirms, the quality of the father's influence is an important moderator [Jaffee et al., 2003]. In Addition, these results are consistent with the view that some degree of parental control reduces the risk of externalizing problems in children [Coley, 1998; Paquette, 2004]. The selfregulation deficit underlying physical aggression in children is difficult to treat [Frick, 2001], so strategies that help young children learn to regulate aggressive emotions are in demand and could become the basis for a treatment program for children with behavior problems [Lochman, 2006]. The current findings raise the possibility that improving the quality of father–child RTP could be a target of intervention with these kinds of children.

On the other hand, these findings seem to contrast with previous work suggesting that "horizontal" parent–child play interactions (i.e. interactions characterized by reciprocity and shared power) tend to provide children with the best opportunities to develop peer social competence [Russell et al., 1998]. For example, Lindsey and Mize [2000] had fathers and their children engage in toy-mediated physical play and showed that children from dyads high in mutual compliance—where partners tended to respond favorably to each other's initiations—tended to be more socially accepted at school. Although we did not assess mutual compliance, our results may be more consistent with those of another study by Barth and Parke [1993]. In that study, the authors showed that parent–child physical play interactions (which included some RTP behaviors), characterized by a controlling parent and a resisting child, or by a directing child, were negatively associated with adjustment to school entry. Like in our study, the resisting and directing children could be conceived as more dominant, relative to other children, in their father–child play interactions. Taken together, these studies suggest that an optimal power balance is likely to provide the best adaptive outcome.

For example, that father dominance during RTP specifically is more closely related to the development of selfregulatory abilities than dominance in other play contexts. Paquette [2004] specifically argues that optimal father–child RTP involves some degree of control by the father. RTP is an emotionally charged activity. Because preschool-aged children are just learning how to regulate their own behavior, these interactions can be especially challenging. An optimally firm and assertive playmate is likely to be more important in this "hot" play context compared with "cooler" play contexts such as a board game. This hypothesis could be tested by examining the impact of dominance during several types of play interactions (including RTP) on the development of aggressive behavior.

Limitations and Future Directions

This study has several limitations. First, the hypothesis tested is based on an assumption of socialization theory that father–child play affects the child's psychosocial development [MacDonald and Parke, 1984]. While the results reported here are consistent with this assumption, they are based on correlations and alternative accounts of the correlations are certainly possible. For example, temperamental characteristics of the children could influence the parents' responses during play [Kochanska, 1997]. Highly sociable children may elicit a more cooperative play style from parents [Russell et al., 1998]. Furthermore, aggressive children are known to have poor selfregulation abilities [Séguin et al., 2004; Séguin and Zelazo, 2005] and, as a result, they may be more difficult to contain and control during RTP, which would make the activity less enjoyable for more timid fathers. These alternative accounts could be addressed in future studies that control for these individual characteristics in longitudinal designs.

Whether RTP and dominance have a developmental impact on aggressive behavior could be addressed with a longitudinal study observing father–child RTP in the preschool years and psychosocial adjustment a few years later. There may be reasons to expect such an impact given the findings that parent–child physical play is known to be associated with later competence in peer interactions [MacDonald and Parke, 1984], and peer RTP, in particular, is known to be associated with social competence [Pellegrini, 1993], social skills [Pellegrini, 1992], and popularity [Pellegrini, 1994]. Nonetheless, the current findings warrant further research on the qualitative aspects of play and an understanding of how power dynamics during play evolve over time. It may be critical to know, for example, that RTP is helpful to some physically aggressive children under certain conditions and harmful to other aggressive children under different conditions.

A second limitation of this study is related to the specificity of the hypothesized effect of RTP on physical aggression. The theoretical models reviewed here suggest that RTP has a unique impact on the development of physically aggressive behavior. However, this specificity of RTP to physical aggression cannot be definitively established with the current data. The dominance data were collected from in-home observations of dominance during various types of play interactions, including RTP. We assumed that the dominance dynamics observed during play in general applied to these RTP interactions. We adopted this approach to maximize the ecological validity of the study design, reasoning that it would be awkward to tell fathers and children when and how to play specific games. However, we only collected frequency data about RTP and not other specific types of play, so we could not compare the interaction of dominance and RTP to the interaction of dominance with other specific play types in predicting aggression. Nonetheless, we were able to generate some support for the specificity of RTP assumption, by demonstrating that the observed interaction between RTP and dominance in predicting physical aggression was maintained after controlling for the frequency of play in general. A follow-up study might have participants to engage in various specific play interactions. While this may be less ecologically valid, these data would shed some light on the specificity of RTP proposed here.

Third, it is worth noting that the current conceptualizations of aggression and the regulation thereof are probably more pertinent to some forms of aggression than others. However, this study employed a basic empirical measure of physical aggression: father-reported frequency of specific physically aggressive acts. This measure does not take the motivation or cause of the behavior into account, even though the regulation of these two types of behaviors is likely to be different. Researchers often distinguish between two broad categories of aggression [Dodge, 1991], proactive and reactive [Dodge et al., 1997; Vitiello and Stoff, 1997]. Within this framework, it is possible that father–child RTP is more closely related to the regulation of reactive aggression because RTP tends to be a physiologically arousing activity. Future studies could address this issue with more detailed assessment of aggressive behavior, including perhaps other forms of aggression such as proactive, reactive, or social aggression.

Fourth, caution is warranted in the generalization of the current results because of a potential self-selection bias. The fathers who participated in the study were volunteers who answered notices posted in community health centers and local cafés. The sample was slightly older and more educated than would be expected in a randomly selected sample of 2- to 6-year-old children.

Finally, future studies may also include a more sophisticated measure of RTP frequency. This study used a single, selfreport questionnaire item about play fighting. Play fighting is merely one type of RTP and future measures may target other types in addition. This future measure could also include objective time anchors for the frequency of play to improve the validity of the data. Furthermore, because RTP is often misconstrued by adults as dangerous or violent, respondents may have tended toward more socially desirable answers. This limitation could be resolved with questions about different aspects of RTP as well as the respondents' attitudes toward the activity. Finally, soliciting another member of the household, such as the child's mother, for information about father–child play frequency and quality will allow for a multi-source assessment of RTP and improve the reliability of the construct.

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