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How does a 4-week motor–cognitive training affect choice reaction, dynamic balance and cognitive performance ability? A randomized controlled trial in well-trained, young, healthy participants

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Abstract

Background: We aimed to investigate the potential effects of a 4-week motor–cognitive dual-task training on cognitive and motor function as well as exercise motivation in young, healthy, and active adults.

Methods: A total of 26 participants (age 25 ± 2 years; 10 women) were randomly allocated to either the intervention group or a control group. The intervention group performed a motor–cognitive training (3×/week), while the participants of the control group received no intervention. Before and after the intervention period of 4 weeks, all participants underwent cognitive (d2-test, Trail Making Test) and motor (lower-body choice reaction test and time to stabilization test) assessments. Following each of the 12 workouts, self-reported assessments (rating of perceived exertion, enjoyment and pleasant anticipation of the next training session) were done. Analyses of covariances and 95% confidence intervals plotting for between group and time effects were performed.

Results: Data from 24 participants were analysed. No pre- to post-intervention improvement nor a between-group difference regarding motor outcomes (choice-reaction: $F = 0.5$; time to stabilization test: $F = 0.7$; $p > 0.05$) occurred. No significant training-induced changes were found in the cognitive tests (D2: $F = 0.02$; Trail Making Test A: $F = 0.24$; Trail Making Test B: $F = 0.002$; $p > 0.05$). Both enjoyment and anticipation of the next workout were rated as high.

Discussion: The neuro-motor training appears to have no significant effects on motor and cognitive function in healthy, young and physically active adults. This might be explained in part by the participants' very high motor and cognitive abilities, the comparably low training intensity or the programme duration. The high degree of exercise enjoyment, however, may qualify the training as a facilitator to initiate and maintain regular physical activity. The moderate to vigorous intensity levels further point towards potential health-enhancing cardiorespiratory effects.

Keywords

Integrated multimodal training, cognition, coordination, dual task

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Background

C e . ea c gge ! . a e c e o . e < oac c g . e ab . e a age c a e .[1,2] A o b e de g < ec a < gge . ed e e c e- d ced e ge e a d ce a ed . e c ec. be. ee a e , a e a ca ce a e b d c a . Be d . e e o . - e ed effec f < . a g e , d a a < a e a . e effec . A d a a f < a e < t e . a d t

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cg. eac. e ead o <. e eec. ea.e. , a g. ex < a < o eb. cg. ead < . fc- . [3] Add gac g. eoa.. e ec e ece e oec.ed . e a ce. e be efc a effec. f o ca. a g e- oa. c. ad cg. .[4] T ec < ba f < . e-b d c da ad cg. e d a- ad c ce- eac. .a < a be c ac < b ed. a g.

I a ece. d, c ac < b ed da- a. a g fc g a oe ce o , oe o e a a fe d, < b e e c d a a d ada o . fa aca- e ge a bee de < . a ed. e a ce ba oa. c. .[5] T e. a g e a ced f c. a c ec. . , o e < a- b d ced b ce a ed ba eg c -ac. a. . T e . e e. < o ex e. ed . e De x a ca . d ca ed L fe K e. c, a. o ca < . cg. e. a g fc d- a . a . ce a g c < o e . . T e. a g c < b ed . add. ecg. e. a a < ed. . a o. e g < & . A . g . e . e e. a e. ed . be ad o ed a e. c o o a. a t, a . d o o a . o ca ac. . . a a c ded . e De x a ca . d .[5] F . . d ca e effec. f . e . a g cg . e ab . e e fe b ., b. , g < ex , oa a ab . , a d f d . e ge ce, oa. c a ede . a g ad . .[6] I c . a . , . e . a- g d ced g f ca . effec. cg . o ca ac. e oa. c oa . . . e a x e d ; b . a < o e- < e . c d a e oe f < a ce a f d . e a x e . a gg o, c a age . a . e e . ec . g o.[6] I . d e c d e a d ad ce ce . a e e , e . a g ed . e x a c < o ex e . e c . ed b . e e cg . e . a g e e a d c d a .[7] a d f . ba oe c f c d a . a c d a . e . .[8] If . e e f d g ca be . a fe ed . ad e . e . ab e. B . . e de g f . e . e e . (< . cg . ec < - b a a d e . a g f e . f . e e ab . e) a d . e c . e a f d g o ca ac. e a d g g . ed ab e (be ef . c d a a d be ef . cg .) ca f a < e de . a ed e . ga o . e . a effec. f . e . e e. < . cg . e c d a ab . e .

We . a < ed . e . ga e . e o . e . a effec. f a < . cg . e d a- a o ga x < e a c ec. e f o ca ac. e gad . . We o . e e . a . e o- ga x < e ce a e < . cg . ec d a ab . e ec ce eac. a d d a x c ba a ce ab . e c < - oa ed . a ac. ec . g o.

Methods

Study design and ethical aspects

We ad o ed a a d < ed-c . ed, g. d a . d de g . T e . a a a o o ed b a ca e . e c c < < . ee a d c d c.ed acc da ce . . e e. ca . a da d e b . e Dec a a . f He (1964) . . < d f ca . (F . a e a 2013). Eac o a . c o a . g ed f < ed c e . o . . d e < e . .

Participants

A . . a f 26 ea . a d ad . < a e a d fe x a e (age = < ea 25 ± . a da d de a . (SD) 2 ea ; e g . = 176 ± 6 c x ; e g . = 71 ± 9 g; 10 < e , 16 < e) e e ec . ed. T e o a . c o a . e e . de . a acade c o . c- e ce o g a x < e a d e o . ed eg a e gage x e . o - ca ac. . . E c c . e a c ded e gage x e . . e . eg a ed < . < da e e c e eg < e , ac . e - e , d e a e f e c g eab . o ca o e f - < a ce , e . a e f b . a ce < d f g o e ce o (e.g. d g < ed ca). T e o a . c o a . f (C da ed S . a da d f Re o . g T a (CONSORT)) g t e F g e 1.

Experimental setup

P . a d f g a 4- ee - . e t e . o e d , a o a- . c o a . o e f < ed c g . t e a d < . . e . A c g . e . e . g ba . e (d2 . e . , T a Ma g T e . (TMT)) a f - ed b a < . . e . ba . e (c ce- eac. . a d d a x c ba a ce). F g . e < ea e x e . , e o a . c- o a . e e a d < a ca ed (1:1, c < o e . e ba a ced a- d < a , BIAS f W d (e 11.02, 2016, G e e U e . f F a f .)), e . e . e . e . g o (IV) . . e c . g o (CG). T e IV t e f < ed . e a g . e e . f 4 ee , . ee o e ee . T e o a . c o a . t e e e c ded a d o f . e c < o e ed e . a 9 (. f 12) e t e . e . e ca e f c < o e e da a e (o e o . c a a). T e CG ece t ed . ea < e . .

The intervention

T e . e t e . a a o o ac a de t ed f < c ce o a < - g . c ec < . a d b a ac . t e ed b c g . t e a . T e e e c e . . . d e e a da o ed f < . e L fe K e . a g c ce o . T e d ffe e . e e c e e e o e- f < ed (Tab e 1), a d eac be e c e a . ed a ea . 2 x . Eac a a d ded . e e . c ea g e e c e e . ; a g e e a t e a eac ed f . e o a . c o a . a ab e . ade a e o e f < . e a . Se e a . , f e a k- o e, ba , ca f , a d a o ed adde , t e e ed.

Cognitive assessment

T e d2 . e . a e e c ce . a a d a . e . . I a . e a c . e . a d a d < ea x e . .[9] T e . c - . fa o a o e . 14 t f ed . ‘d’ a d ‘o’ e . e . O e a d/ be ea eac e . e , a < be f . e a e o a ced (. e . . . e b . e a d be eac e . e). T e o a . c o a . . a . fg e . a d < a

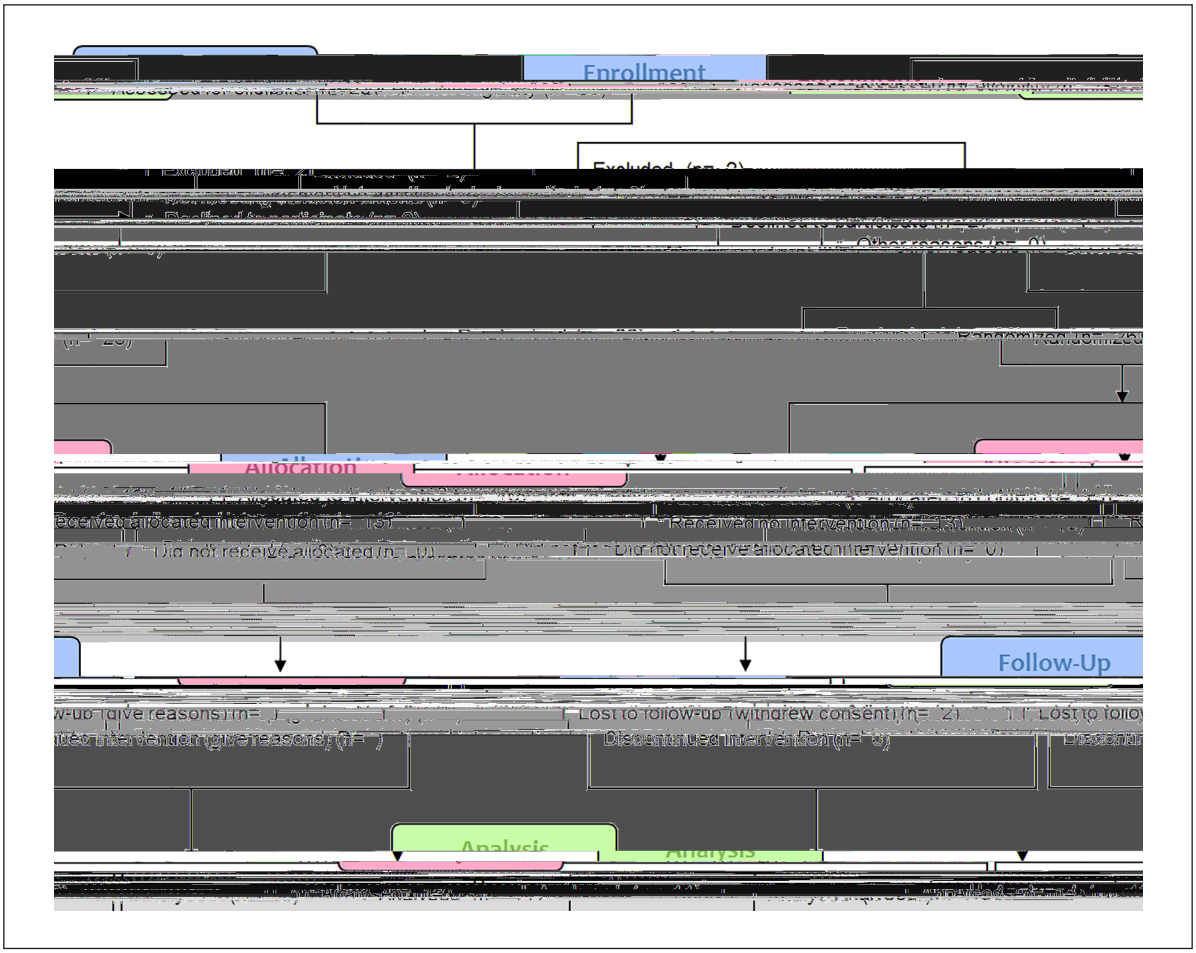

Figure 1. Study and participant flow (CONSORT). N, number.

Table 1. The 10 categories of exercises used during intervention with description of the content and examples.

Number and name	Content	Example
1. Parallel ball	Throwing two balls upwards, cross the arms and catch the balls	
2. Speed ladder	Jumping through a speed ladder with cognitive perturbation	Recite the alphabet
3. Go and throw	A trainer calls different commands while walking and throwing a ball	Throwing the ball and stepping forward, backward and sideways
4. Passing a ball	A trainer gives a command while he or she throws a ball, the participant had to catch it in different ways	While stepping with one foot forward
5. Dancing with a scarf	Different scarf movements and stepping combinations	Circle a scarf with one hand and throw a ball with the other hand
6. Finger skills	Upright standing, knees slightly flexed. An examiner gives the respective command, based on a random order	Left and right hand alternating have to show/mimic the letter 'L' and 'O'
7. Hand skills	A trainer gives commands for moving both or one hand in different directions	Up, down, to the right and to the left
8. Head skills	A trainer calls the direction the participant shall look and simultaneously has to point with his hand into the other direction	
9. March parade	A trainer calls different numbers with different meanings, touching one leg with one hand	#1: right hand touches the right thigh; #14: sidestep left and the leaving the right hand
10. Imitation	A presentation is shown where triangles are placed at the body parts the participant should lift	Hands, arms, feet and legs

a ‘d’ e.e . (. .a). . e. F eac e, e. d a 20 ec d. C ce. a , c < o.ed a d c - e ed.a ge < c < .. ed < .a e, a ed f f . e ca c a .

T e TMT ca o e t a ea c e c. ad o ce g oeed.[10] We ed a d g.a e t c e b < de.a e . g c ea . . e oa oe -ba ed e .[11] T e e - ab . f. e TMT a bee f d. be t g .[12] T e. d ded . oa . A a d B. I oa. A, . e oa. c oa , a c a o be, ad. c ec. 25 < be a ce d g de. I oa. B, oa. c oa ad. c ec. < be a d e - . e a. e a g < a e (1 A 2 B e c., . 13). T < e . c < o e e eac TMT a « o ed f f . e a a .

Motor assessment

C ce eac . e . (. ac a c e a c eff c e . (ICC): 0.89) a oe f < ed . e Q c B a d (T e Q c B a d, LCC), a oa e (100« × 76«) e oo ed . f e e oad (ooe g . a d ef , e g . a d ef , a d ce . e) ed . a c . b , o d g t a . < a d feed- bac f < a a f e g ! c e o d g . . e e oad .[13] F . e . t t g, oa . c oa ! . a . ed o g . . a d g e . a o . , . . e g . f . o aced be . ee ooe a d e g . e a d . e ef . f . be . ee ooe a d e ef . e . B . fee . dd . . c . ce . e e . Af . e a 5« c . d , e f . e f e g ! , e o e e . g . e f . e e ec . b , . . Pa . c oa ! e e a ed . . a o a fa . a o be . . e g . ef f . . e e oec . e e . e b a d . T e ooe a d e g . e t a d . be . a ooed . . e g . f . a d . e ooe a d e ef . e e . . e ef f . . T e ce . e e ca be . a ooed . . e g . ef f . . Af e . a oo g . e c ec . e , a e g . . a d < . T e oa - . c oa ! . e e . ed . e e . a o . a d . a ooed . e e . d ca ed e . T e < be f c ec . f . c . ac d g . a . < e (10) a d a e age eac . < e e ec ded . T e . g o ced e a e oea ed . . < e af e 60 f e . o g . a d g, e oec . e .

T e . < e . t ab a . e . (TTS) a t ed . < ea e d a c o . a c . af e a e - egged c . e < t e - < e . < o f e f e eec ed g a d g e eg t . a d . a ce . Pa . c oa ! ’ eg e g a < ea ed f < . e . - c a . e < a . . e < a e . T e oa . c oa ! . a . ed . a d - g . e d < a . eg f . f . e f ce oa e . Af e a d g . e a x e eg, . e e e ! . c . ed . ! a d a ! . a o be, o . g . e a d . e o a d g a . a < a e a ead f . « o aced a . e a . T e d a f eac < ea « e . a 20 ; . e oa . c oa ! ad . c < o e e f . a . T e . < e . ! ab a a c < o . ed a . e . < e . g d eac . f ce e . ed . ! ab . (« ea g d eac . f ce e . a d a ± 0.25 SD)[14] a d . e < ed a a e f . e f e . a ! a ed f a a ! . T e TTS a < t de a e . g e ab . . .[15]

Self-reported outcomes

Se f - e o . ed a g f c d a t e e o e f < ed bef e a d af e . e o g a « e. T e oa . c oa ! ad . dge . e a d e e c d a , eac . . a d ba a ce ab . . ega d . da g a d o . g ac . t . e . F eac f . e oa a « e e t , e oa . c oa ! e ec . ed . e e f - e . < a . ed ab . a < e ca a g ca e oa g f < 1 (o). 10 (e ce e .).

I add . . . e e o e - a d o ! . - . e t e . a g , e f - e . < a . ed da a e e c ec . ed f g eac . a g e e . e . e ! g o. T e oa . c oa ! a . ed e e c e e < e . ega d g . ef ! ed . . a e a a . c oa - . f . e e . e a d a ca e f < 1 (f / a . c oa .). 5 (« a < a f /a . c oa .).[16] T a e e f - e o . ed e e . , B g a g f o e ce ed e e . (RPE) e e a e ed ! g a 6 20 - o . L e . - o e ca e .

Statistical analysis

S . a ! . ca ca c a ! e e o e f < ed ! g SPSS S . a . e 23 (IBM, 2015), BIAS f W d ! (e 11.02, 2016, G e . e U e . f F a f .), E ce (M c ! f , 2016). T e e f g f ca ce (A o a) a e . 5% f a ! . a . - ca a a t e , o - a e be e c de ed g f ca . . U t a a e ga t . a a t e f c t a a ce (ANCOVA), ! g . ed ffe e ce be . ee . e o e - a d o . - e ! f . e « a oa a x e . e , e e o e f < ed f . e de . ec . f g o d ffe e ce (af e c ec g . e de g a < o). T e ba e e a t e e e ed a c - a a e . I . ec a e f g - f ca ce, ab . e - a f < ed (. ec a e f . « a c c - t a a e f e ce) o . c a a t e f g o d ffe e ce e e ca c a ed .

Results

T oa . c oa ! (c . g o) . d e . e c t e . f oa . c oa . . ! a g a ea ! . N oa . c oa ! . ad . be e c ded . T ! , da a f < 24 oa . c oa ! (13 . e t . a d 11 c .) e e a a ! ed . O e a , . a g f e c a 2.7/ ee (±10.6 . a g t d g . e . e . oe d). C < o a ce a e a . ! 88%. O a d d a e e , =5 . ee oa . c oa . ed eac f . e c ed ed t 12 . a g , =2 11, =2 10, a d =4 9.

Motor function

T e ANCOVA f < . f c . d e « ! . a ed be . ee - g o d ffe e ce (c ce - eac . : F=0.5; TTS: F=0.7; o > 0.05). Ba e e a t e e e (« ea ± SD): c ce - eac . : IV: 12.1 ± 1.2 ! , CG: 12.1 ± 1.4 ! ; TTS: IV: 1.51 ± 0.3 ! , CG: 1.44 ± 0.2 ! . T e o e - . o . - d ffe e ce f eac g o a e ! . a ed F g e 2. W e o e - . o . - d ffe e ce cc ed . e TTS, b . g o c ea ed . e < be f ! . e c ce eac . e . .

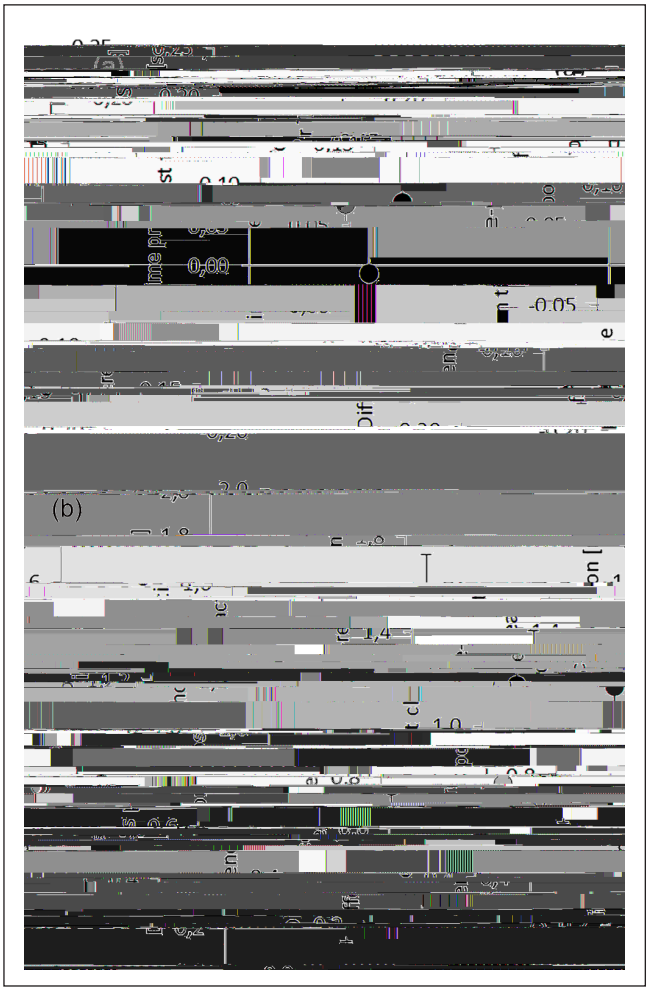

Figure 2. Mean and 95% confidence intervals for the pre- to post-intervention period differences in functional outcomes: (a) time to stabilization test and (b) choice reaction test. Δ = difference in pre-to-post; s = seconds; hits = number of hits in the choice reaction test.

Cognition

C < oa ab e e ! a e . e c g . t e . e ! (D2: F=0.02; TMT A: F=0.24; TMT B: F=0.002; o>0.05). T e c e o d g o e-. o . -d ffe e ce f eac g oa e - . a ed F g e 3. Ba e e a e e e (ea ± SD): TMT A: IV: 11.6 ± 2.7 ; CG: 14.1 ± 2.3 ; TMT B: IV: 26.6 ± 12 ; CG: 27.2 ± 7.6 ; d2 e f e e c : IV: 11 ± 9, CG: 18 ± 11.

Self-reported outcomes. T e . c < e f RPE < a < < , RPE < ea , a d f a d o ea a . a . c oa « a ed c a ged d g . e . d oe d (o>0.05). F g e 4 d - o a . e a e f eac . a g e .

F a a ed g d g . e e . e t e . S < a ; < . oa . c oa ! ed f a d . e e . a - g e . Pe ce ed e e . a c . a . a a a e age e e be ee 10.3 a d 12.2 a da a < a < < e t e be ee t 12.7 a d 14.3.

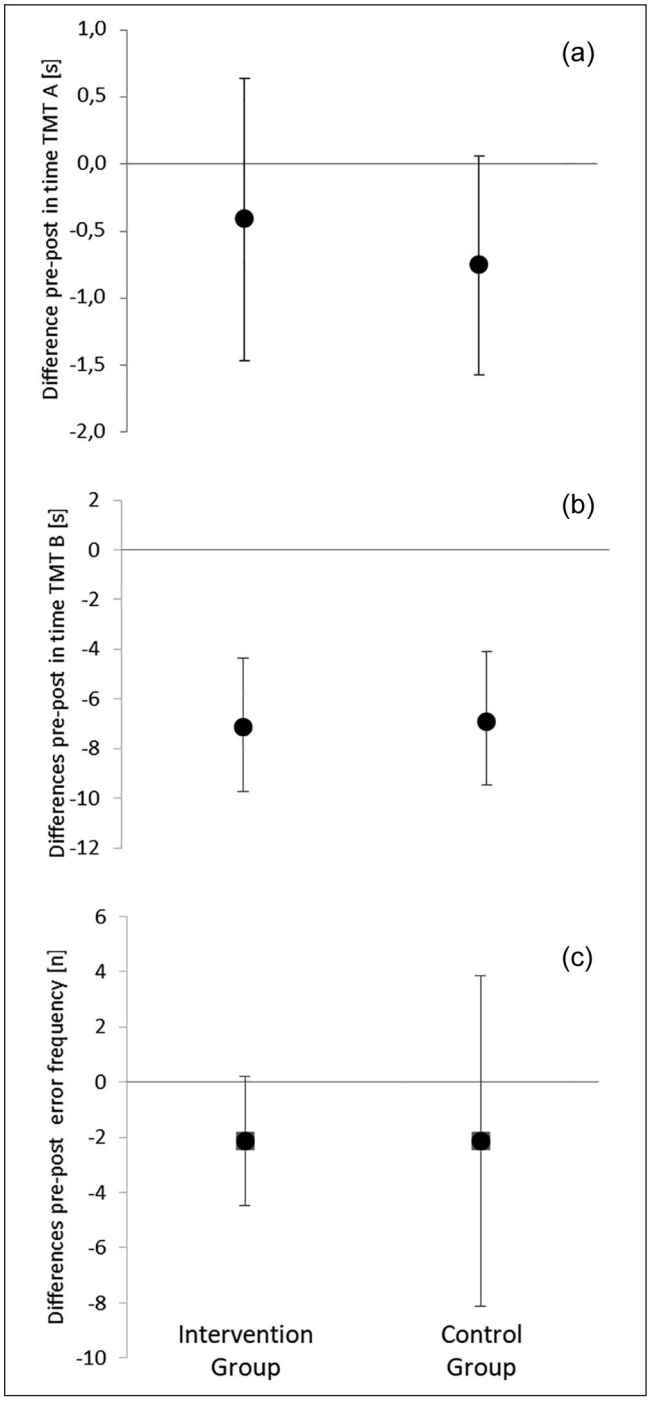

Figure 3. Mean and 95% confidence intervals for the pre- to post-intervention period differences in cognitive outcomes: (a) time for the Trail Making Test A, (b) time for the Trail Making Test B, and (c) D2 frequency of errors F; n = numbers.

Discussion

We ad ed a < . c g . t e d a - a o g a « e a c ec e f o ' ca ac t e, g ad ! , a < g . c ea e c g . t ea d < . ab . e . N add . a effec f . e < . c g . t e < . < da . a g < .

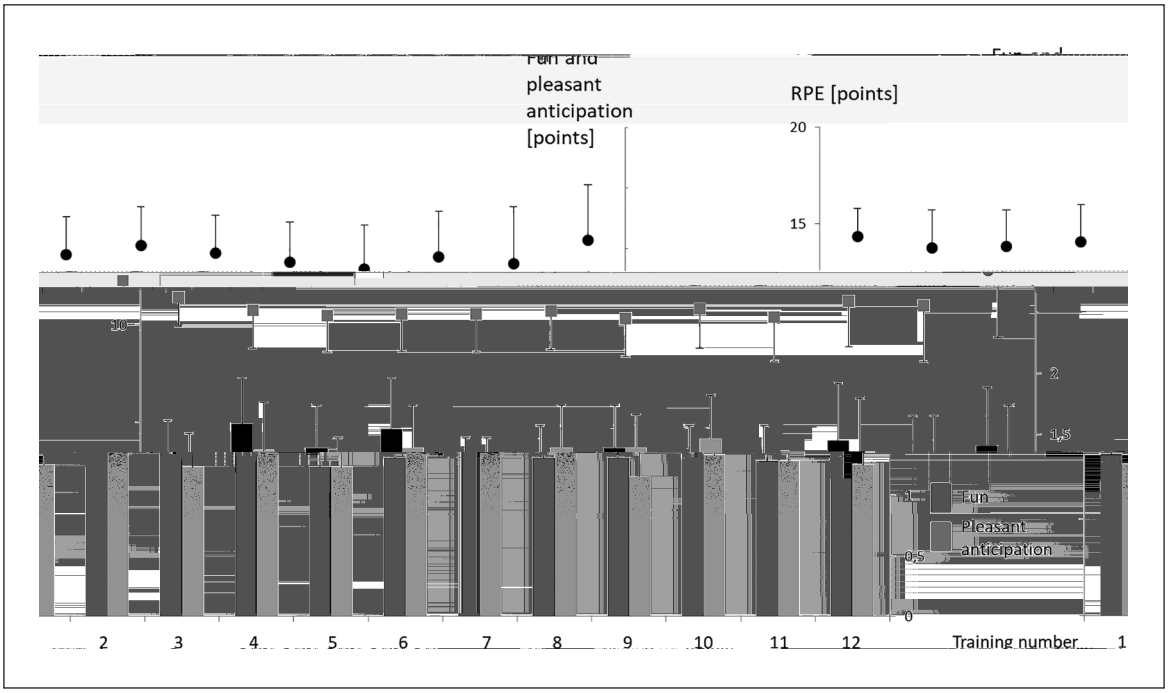

Figure 4. Self-reported outcomes at each training session. Fun and pleasant anticipation (right y-axis) are displayed as bars; maximal (upper dots) and mean (lower dots) RPE values (left y-axis) are displayed as points. Error bars display 95% confidence intervals.

[illegible].[21] He ce, a d a. [illegible]

[illegible]

Conclusion

We de [illegible] 4- ee [illegible]

Declaration of conflicting interests

[illegible]

Ethical approval

[illegible] (2016-47).

Funding

[illegible]

Informed consent

[illegible]

Trial registration

[illegible]

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Da e N ede e [illegible] ://[illegible]/0000-0002-7690-5418

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