ISSN 1512-1801

ISSN 1512-1801

DUAL-TASK PERFORMANCE AND WORKING MEMORY CAPACITY FOR SPORTING PERFORMANCE

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Abstract

The ability simultaneously coordinate two tasks is an essential cognitive function necessary in implementing sporting performance. It was investigated whether laboratory paper-and-pencil dual-task methods and Working Memory capacity predict off-field dual-task sport performance and on-field competitive performance; whether off-field dual-task performance can predict on-field competitive performance; whether task difficulty affects dual-task performance. Study was performed on less skilled and highly-skilled professional rugby players. Study found significant effect of increase of task complexity for both study groups but highly-skilled professional rugby players performed better on dual-task than less skilled players. It was found predictive capacity of paper-and-pencil and off-field dual-task performance for on-field competitive performance.

Keywords: *draw-and-pass performance, Off-field dual-task performance, competition draw-and-pass performance, paper and pencil dual-task, highly-skilled professional rugby players.*

Introduction

The central executive is the less well studied component of working memory. One of the important functions of it is the ability simultaneously coordinate two tasks. Dual task coordination is an essential cognitive function necessary in implementing of both everyday tasks and sporting performance. Dual-task paradigm proved to be the sensitive tool for detection of cognitive decrement in early stages of Alzheimer's disease [1-6], vascular dementia patients [7-8], patients with Parkinson's disease [9], showed impairment in patients with hippocampal damage [10], in adults with autism [11].

Sporting situation – sporting performance during competition require performance of multiple tasks simultaneously [12]. Dual task coordination is an important ability needed for successful sport performance and its contribution may be different in different stages of sport performance. The dual-task approach was devised for the purpose of close replication of the real acute game situation where player is required to catch and throw the ball while at the same time monitor the positions of opponents and team-mates [13]. The dual-task coordination in sport is not yet extensively researched [13-18] and needs further investigation that is a purpose of the presented study. Research using the dual-task paradigm tells us that under dual-task conditions there is a decrease in sport performance particularly in early stages of practice [15-16] thus dual-task performance of sporting skills can contribute in differentiation of expert athletes from novices in the situations when such differences are not evident from sporting skills performed alone [19]. The dual-task proficiency

ISSN 1512-1801

affects sport performance [20] and may be a more appropriate way to assess the skill proficiency in athletes [21].

Several studies are devoted to the investigation of relationship between psychological laboratory tests, off-field sport performance task and on-field, competition sport performance and some of them substantiate the view that laboratory tests of cognition may indeed enlighten the sport-cognition relationship [22-26]. One of the purposes of the present study was investigation of relationships between laboratory psychological and off-field sport performance tasks with on-field, competition sport performance of dual-task coordination in rugby players. Despite existence of restricted number of studies on this topic [17-18] further research is warranted for validating off-field dual-task coordination method that will reliably predict on-field, competition sport performance.

Since general working memory capacity (WMC) is an important factor affecting performance of everyday tasks it could make contribution in differentiating of novice and experienced athletes' performance on dual-task paradigm. There are controversial findings on differences of working memory performance in less skilled versus high skilled athletes. Hambrick & Meinz (2011) in their studies demonstrated that WMC was associated with superior performance in complex tasks even in expert individuals with high levels of domain-specific knowledge [27]. Vestberg, et al., 2012 showed that professional soccer players had higher scores on a standardized measure of executive functioning which is closely related to WMC (D-KEFS) [28] than lower level soccer players and a standardized normal population. According to these findings can be suggested that a good team player could be characterized by excellent spatial attention, divided attention, working memory, and mentalizing capacity. However, other studies didn't find any differences in WMC between expert athletes and standardized control populations [29], between expert team sport athletes, expert track athletes, and novices on several attention tasks [30], the spatial storage component of working memory between experienced basketball players and college students with no team-sort experience [31]. Thus it is still necessary to investigate whether general working memory capacity determines sporting performance and the factors affecting the relationship of these two constructs. The presented study makes contribution in clarification of this relationship.

In different previous studies of dual-task coordination in laboratory settings the dual-task paradigm was studied by coordination of different types of single tasks. Majority of single tasks were not titrated to the individual levels of participants which is an important procedure to differentiate effects of task difficulty from the subjects' ability of two task performance in coordination. In most studies using titration procedure a computerized version of the dual-task was used [1, 32, 33, 5]. The performance of computerized dual-task requires a light pen that is not a standard piece of equipment in most laboratories and computer programs to run the tasks, which may not readily transferable from one computer to the other. Therefore a paper and pencil version of the dual-task paradigm was devised [34, 2]. The paper and pencil version of the dual task was refined and the "Tbilisi paper and pencil motor task" was made in a user-friendly form [35]. In the presented study the refined paper and pencil motor task was used for investigation of the dual-task performance in laboratory setting by rugby players. This method was first time used for the population of athletes.

Analysis of tries in previous studies [18] showed that in all activities leading to try approximately 49,5% of tries were scored from draw-and-pass activity that shows importance of the draw-and-pass performance for study purposes to assess dual-task coordination ability of athletes. Thus draw-and-pass activity was selected as a primary motor task for off-field and on-field competitive dual-task performance for rugby players.

The study aimed at investigating *dual-task* coordination in sport performance:

1. Whether laboratory paper and pencil dual-task methods can predict off-field dual-task sport performance and on-field competitive performance in real game situation.
2. Whether off-field dual-task sport performance can predict on-field competitive performance in real game situation.

3. Whether laboratory paper and pencil dual-task methods, off-field dual-task sport performance and on-field competitive performance in real game situation differentiate expert athletes from less skilled matched on age and IQ.
4. Whether WM capacity (Working Memory Span) determines differences on off-field dual-task sport performance and on-field competitive performance in real game situation of less skilled and expert athletes matched on age and IQ.
5. Whether any increase of the task difficulty in dual-task paradigm would disproportionately affect less skilled and expert athletes matched on age and IQ.

Methods

Participants

Study of dual-task performance was performed by forming groups of less skilled rugby players and highly-skilled professional rugby players. 15 less skilled rugby players were recruited from the semiprofessional rugby teams defined as rugby players that had playing experience less than 15000 working hours in rugby with mean age of M=20.9 years (*SD*=1.6), with mean height of M=183.5 cm (*SD*=3.8) and mean body mass of M=98.4 kg (*SD*=1.8). 17 highly-skilled professional rugby players were recruited from the professional rugby teams of the Georgian National Rugby 15 defined as rugby players that had playing experience more than 17000 working hours in rugby with mean age of M=21.1 years (*SD*=1.8), with mean height of M=184.4 cm (*SD*=4.2) and mean body mass of M=96.3 kg (*SD*=0.7). The groups of novice and highly-skilled professional rugby players were matched on age and IQ. There was no significant difference between mean age of two study groups ($t(30)=1.281$; $p<.131$).

Material

General intelligence level of participants was assessed by the WAIS-III [36].

The paper and pencil version of the dual-task

The experimental material for the laboratory dual-task experiment was include paper and pencil (“Tbilisi paper and pencil motor task”) version [35, 37-40] of the dual-task (digit span - motor tracking). In the paper and pencil version of the dual-task study subjects were performed the List Memory Task – serial digit recall verbal task and paper and pencil version of the perceptuomotor tracking task singly and in a dual-tasks paradigm whereby the two individual tasks are performed simultaneously.

List Memory Task. Participants listened to lists of digits from a computer and repeated the digits in serial order. All nine digits (1-9) were recorded by a professional TV speaker and after using computer program Cool Edit Pro 2.0 and Superlab 1.03 were randomly combined in lists of digits of different length. In each list digits were presented at a rate of 1 per second. In the Digit Span Determination participants were tested on six lists of the same length, starting with length 2. Participants’ digit span was determined as the maximum length of the lists of which the participants recalled at least 5/6 correctly. In the List Memory Single Task each subject immediately repeated back the lists, the length of which was equal to the subjects span during 1 minute. According to the scoring procedure number of correctly recalled lists was divided by the number of lists presented (the “lists recalled correctly”) [41].

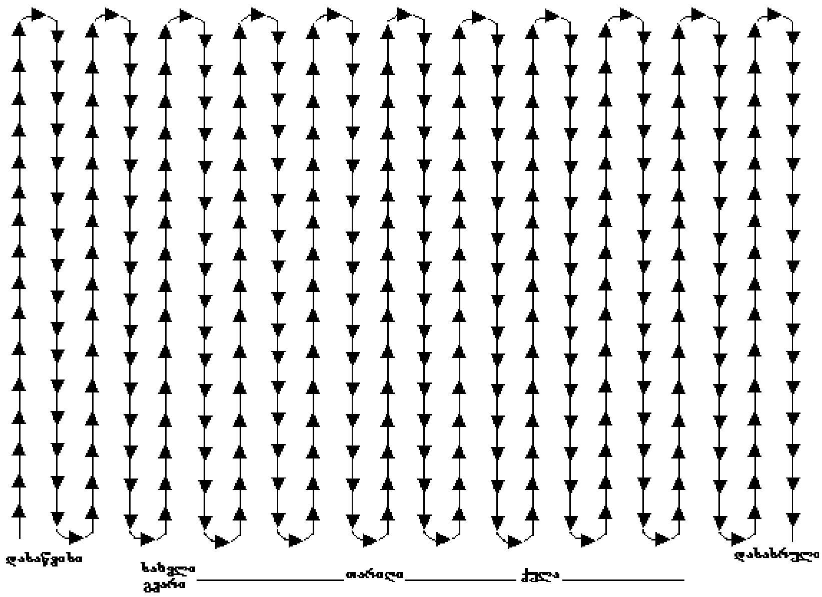
Paper and Pencil Motor Tracking Task. In the “Tbilisi paper and pencil motor task” participants were presented with 373 black arrows arranged in vertical parallel lines linked with each other and forming path laid out on an A3-size sheet of white paper (Figure 1). Height of the tip of each arrow was 5 mm and length of each base was 7 mm. Straight lines linking arrows were 1 cm in length. Subjects were required to use a felt pen to cross out arrows from the start arrow to the end, as was indicated on the paper. They place a cross on each successive arrow as quickly as possible. Number of arrows was chosen so that it is impossible to cross all arrows in one minute. Participants were first given a number of practice trials with a short, 35-arrow path presented on an A4-size paper, to accustom them to the procedure, and to ensure that they understood task

ISSN 1512-1801

requirements. The score of the motor task was the number of arrows successfully marked by the participant.

The Dual-task condition. In the dual-task condition participants performed the tracking task while simultaneously verbally reproducing the lists of digits.

Figure 1. ***The "Tbilisi paper and pencil motor task".*** Pattern of figures (arrows) for motor tracking task.



The working memory span task

The working memory span of study participants was measured by the task was based on the technique used by Daneman and Carpenter (1980). The subject heard a series of short sentences, each involving a subject performing an action, a verb, and an object for example, *Doctors have a profession*, or *Asia is a continent*. Study subjects heard two, three, or four sentences and then were asked to recall the last words of sentences in any order [42]. In order to ensure that the subject comprehended the sentences and didn't merely treat the task as one of verbal memory, they were required to categorize each sentence on the basis of whether or not it made sense. Half the sentences were sensible and half were absurd (for example, *Ants are living creatures* and *Florida is a parent* respectively). After the subject had heard each sentence they responded orally 'true' or 'false'. The test successively involved 3 sequences comprising 2 sentences, 3 sequences with 3 sentences, 3 sequences with 4, 5 and 6 sentences (total of 60 sentences). Subjects were given examples and practise trial with 2 sentences. Presentation of sentences was continued until the participant failed on two or more sentences at a given sequence length. The three longest correct sequences are then taken as the basis for Working Memory Span. For example, with 2 correct sequences of 5 sentences and three correct sequences with 4 sentences, subject's span would be (5+5+4)/3=4.67. English versions of sentences were translated and the task was adapted to Georgian population in previous study [35]. 5 different lists of 60 sentences were prepared. For each participant a list was selected randomly from a set of 5 lists.

Off-field dual-task draw-and-pass performance and competition/on-field draw-and-pass performance

The draw-and-pass performance tasks for rugby were taken from the previous studies [17-18]. In **the off-field draw-and-pass performance task** players performed a standardized 2-on-1 drill in a 10 m × 5 m grid, and a 3-on-2 drill and 4-on-3 drill in a 15 m × 10 m grid under both single-task and dual-task conditions. Video footage was taken from the rear, side, and front of the player using digital video cameras (Canon XA30 Professional Camcorder) to assess whether the ball-carrier achieved the criteria for a successful draw-and-pass. To ascertain that the motor task is properly selected and represent specificity of rugby performance the draw-and-pass performance task was discussed with the expert rugby coach before conducting the experiment. To test the feasibility of conduction of selected task procedure and to got appraisal of specificity of the draw-and-pass task two rugby league players were recruited for the pilot trials of the task. According to this procedure was made modification of the original draw-and-pass task [17-18]. The success of the draw-and-pass (2-on-1) was determined based on the ability of the ballcarrier to meet technical criteria employed to assess the draw and pass proficiency of rugby league players presented in previous studies [17-18] and indicated below. The success of the 3-on-2 and 4-on-3 were based on similar criteria to the 2-on-1, but was also determined based on the ability of the ball-carrier to ‘get the ball to the unmarked player’. The technical criteria employed to assess the draw and pass proficiency of rugby league players include 1) Pass on the inside shoulder of the defender; 2) Small step away from the defender; 3) Body position square with defender; 4) Pass in opposite direction to leading leg; 5) Correctly identify when to pass and when to run; 6) Appropriate distance from the defender to prevent intercept pass; 7) “Take the defender away’’, ‘‘move the defender’’, ‘‘create a gap’’, or ‘‘open a hole’’. Players were awarded one point for each occasion they achieved the relevant criteria and a score of zero if they failed to achieve the criteria. A total score (out of 7) was awarded for each of the trials. In addition, a total draw and pass proficiency score (expressed as a percentage) was awarded based on the aggregate of all technical criteria. All coding of draw and pass performances was performed with the coder blind to the competitive standard of the participant and whether the trial was performed under single- or dual-task conditions. The rugby coach coded the video footage for the number of tries scored, and the activities that led to the try. The video footage also was coded for errors that resulted in a failed scoring opportunity. In the case of draw-and-pass opportunities, the video footage was coded for successful and unsuccessful attempts, 2-on-1, 3-on-2, and 4-on-3 opportunities, and whether the try occurred as a result of a series of two or more draw-and-pass attempts in the same sequence. The intraclass correlation coefficient and typical error of measurement for the assessment of draw-and-pass performances were 0.79 and 0.77 respectively. The video footage also was coded by the second experienced rugby league coach. The second coder was blinded to the results of the first coder. The intraclass correlation coefficient and typical error of measurement for inter-rater reliability for competition draw-and-pass performances were 0.80 and 0.67 respectively.

Duration of one trial of the draw-and-pass was on average 3.6 s (mean=3.6 s, range 2.34–4.18 s). Subjects were warned to continue the draw-and-pass performance until the experimenter stopped players by the voice signal that was presented to players after elapsing of 1 minute.

The off-field single-task condition involved players performing the primary skill of drawing-and-passing in isolation, whereas the off-field dual-task condition required players to perform the primary skill while concurrently performing a secondary verbal task – the List Memory Task titrated to the individual ability level for each study subject. The verbal task was presented by a loudspeaker and responses were recorded by the dictaphone and by a video camera placed directly in front of the player. All single and dual-tasks lasted for approximately 1 minute.

The on-field/competition draw-and-pass performance task was assessed using the video recordings of 10 Georgian National Rugby XV First League Matches of less skilled rugby players and of 10 Georgian National Rugby XV Big Ten Matches of highly-skilled professional rugby players. To assess if ball-carriers achieved the criteria for a successful draw-and-pass performance video recordings were collected from three different angles: a ‘tight’ view, a wide view from the side and a rear view. The rugby coach coded the video footage for the number of tries scored, and the activities that led to the try. The video footage also was coded for errors that resulted in a failed scoring opportunity. In the case of draw-and-pass opportunities, the video footage was coded for successful and unsuccessful attempts, 2-on-1, 3-on-2, and 4-on-3 opportunities, and whether the try occurred as a result of a series of two or more draw-and-pass attempts in the same sequence. The intraclass correlation coefficient and typical error of measurement for the assessment of draw-and-

ISSN 1512-1801

pass performances were 0.84 and 0.62 respectively. The video footage also was coded by the second experienced rugby league coach. The second coder was blinded to the results of the first coder. The intraclass correlation coefficient and typical error of measurement for inter-rater reliability for competition draw-and-pass performances were 0.88 and 0.71 respectively. The reliability of coach's assessment of the on-field/competition draw-and-pass performance was reassessed by analyzing 10 matches after two weeks from the first analysis. The intraclass correlation coefficient and typical error of measurement for inter-rater reliability for competition draw-and-pass performances were 0.76 and 0.54 respectively.

Procedure

The study was conducted in agreement with Helsinki Declaration (1977) regarding ethical standards for clinical studies in medicine. All participants received a clear explanation of the study, including the risks and benefits of all procedures and written informed consent was obtained from all subjects recruited into the study. Experiments presented in this study were discussed and received approval from the Review Board for Humane Investigation of the Georgian State Teaching University of Physical Education and Sport.

All participants were administered WAIS-III to assess general intelligence level of participants and define IQ score. All rugby players administered the working memory span task.

The paper and pencil dual-task experiment was conducted on one experimental session. In the beginning of experiments the Digit Span Determination procedure was performed for all participants. Participants performed the List Memory (single task), the Tbilisi Paper and Pencil Tracking Task (single Task), then paper and pencil dual-task (List Memory plus tracking), the retest of the dual-task condition and lastly the List Memory (single task) and the Tbilisi Paper and Pencil Tracking Task (single Task) were administered again by the same experimenter in order to account for practice, motivation and fatigue effects. Each single task as well as the dual task was last one minute. The presentation order of List Memory and tracking performed as single tasks was counterbalanced across participants.

Before beginning of the task conduction all rugby players were explained and familiarized study procedure. Rugby players were familiarized with the draw-and-pass task procedure prior to the actual draw-and-pass assessment. Players were provided with practice trials on both single-task and dual-task conditions. After practice trial players performed in random order a total of twelve trials. Rugby players performed 2-on-1 drill in a 10×5 m grid, and a 3-on-2 drill and 4-on-3 drill in a 15 m × 10 m grid under single task and dual-task conditions. Six trials were passing to their left side and six trials passing to their right side. Six trials were conducted under single-task conditions, and six trials were conducted under dual-task conditions. Trial order was counterbalanced between participants. Defending players were instructed to defend as they would in a real competitive match and attempt to prevent a try being scored. They were instructed to perform with uniform effort against all participants and under all conditions. All players were tested in similar groups according to their playing position. Players within these groups commonly perform the same types of training based on the physical demands and skill requirements of their position. In addition, the physical qualities of players within these groups have been shown to be homogeneous [17-18].

Data was analysed by SPSS 20.0.

Results

There was no statistically significant difference between the total raw scores of WAIS-III for groups of highly skilled (mean=279.24, SD=72.15) and less skilled rugby players (mean=266.05, SD=79.21), t(30)=1.125, p=.129.

For the WMS scores significant difference was not found between less skilled rugby players (M=3.21; *SD* =.77) and highly skilled rugby players (M=3.22; *SD* =.74) t(30)=0,86 p=0,20 (Figure 2).

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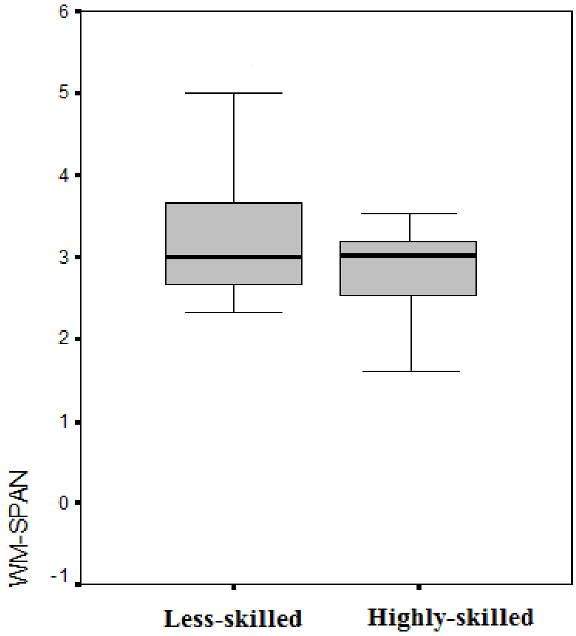
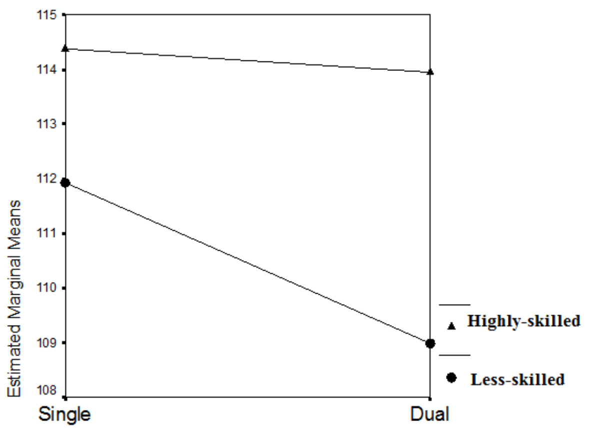
Figure 2. WMS scores for less skilled and highly skilled rugby players.

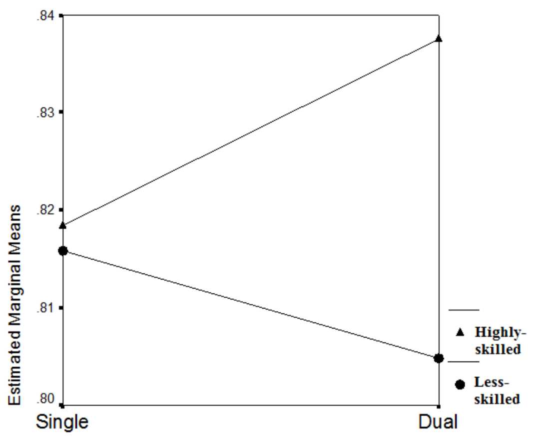


To determine the effect of dual-task on performance of List Memory Task (using digits recalled correctly and lists recalled correctly respectively) and motor tracking, the data from the single and dual tasks were entered separately into a 2 (group) × 2 (condition – type of task: single vs. dual) ANOVA. For the List Memory Task - digits recalled correctly, the ANOVA showed a significant effect of condition, $F(1,30)=8.605$, $MSE=21.776$, $p<.003$; but no effect of group ($F<1$) and no interaction ($F<1$) (Figure 2). For the paper and pencil motor tracking task the ANOVA showed a significant effect of condition, $F(1,30)=8.263$, $MSE=327.771$, $p<.007$ and of group $F(1,30)=35.863$, $MSE=1489.641$, $p<.007$. The effect of group by condition interaction was significant at one tail $F(1,30)=2.909$, $MSE=327.771$, $p<.097$ (Figure 3).

Figure 3. The List Memory and computerised motor tracking task performance for less skilled and highly skilled rugby players.



The List Memory Task.



The paper and pencil motor tracking task

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In the previous dual-task study [33] it was shown that reporting of the patterns for each individual task under dual task condition might be misleading, because this cannot account for the overall changes in performance across both tasks or for trade-offs in performance between tasks. Thus, an overall measure of performance – percentage change, was calculated for each participant. The percentage change combines the percentage change in accuracy that occurs between the single and dual tasks for the List Memory Task and the motor tracking task [43].

The percentage change formula is the following:

$$Percentage\ change = \frac{single\ task\ performance - dal\ task\ performance}{single\ task\ performance} \times 100$$

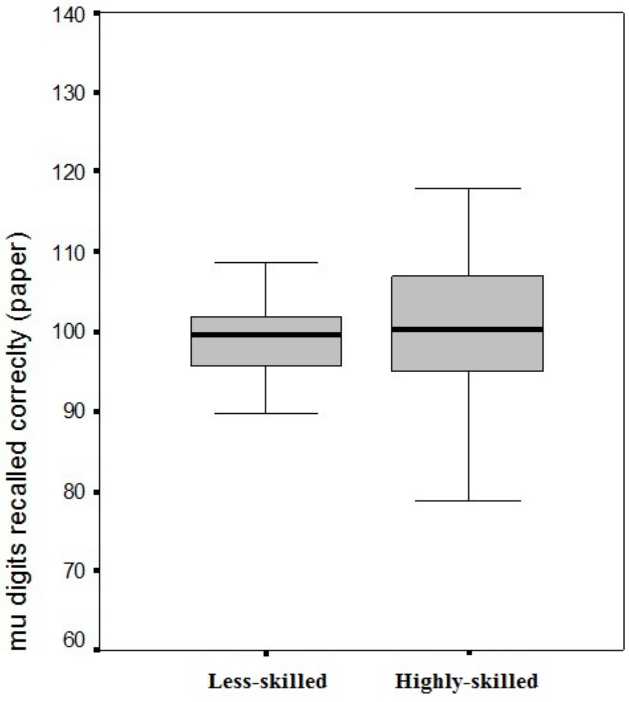
The percentage change for each task was combined as follows:

$$Combined\ percentage\ change\ (\mu\ score) = $$
$$= 100 - \frac{Percentage\ change\ verbal + Percentage\ change\ tracking}{2}$$

When this formula was applied to the validating study, a clear separation between performance of AD patients and control subjects was found [43].

Two percentage change scores were calculated for the List Memory Task and for the perceptuomotor tracking task. μ scores were calculated for less skilled rugby players (M=99.21; *SD* =.12.60) and highly skilled rugby players (M=104.86; *SD* =19.66) (Figure 4). The μ score on computerised motor tracking task was higher for the highly skilled rugby players in comparison of less skilled rugby players but the was significant at one tail t(30)=1.429, p<.057.

Figure 4. The combined percentage change μ scores for paper and pencil version of the dual-task.



To determine the effect of dual task of List Memory Task and draw-and-pass performance motor task, the data from the single and dual tasks were entered separately into a 2 (group – less-

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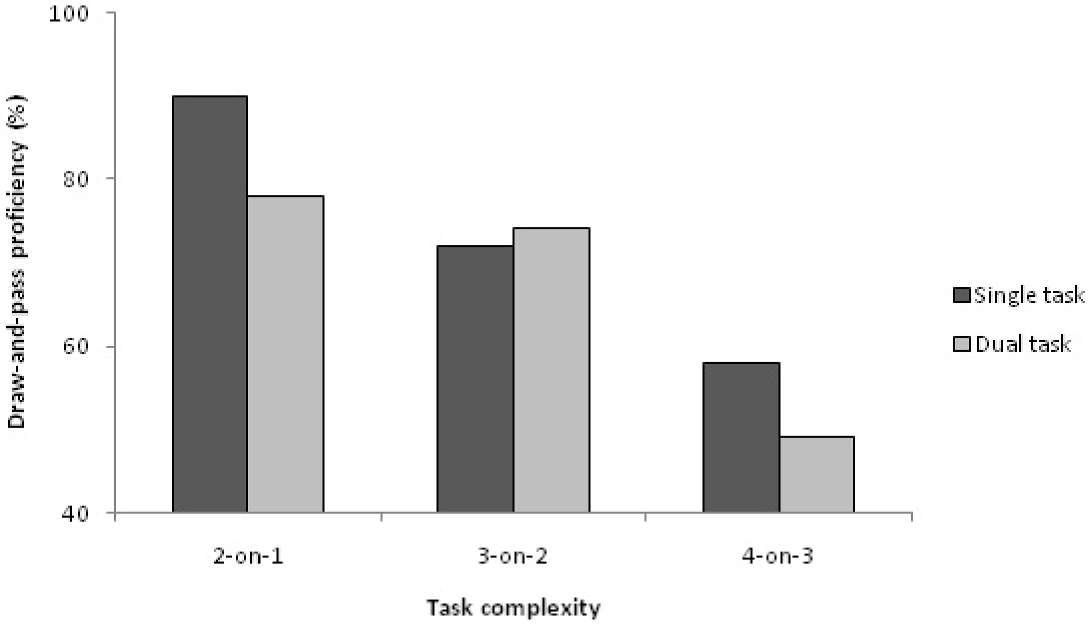
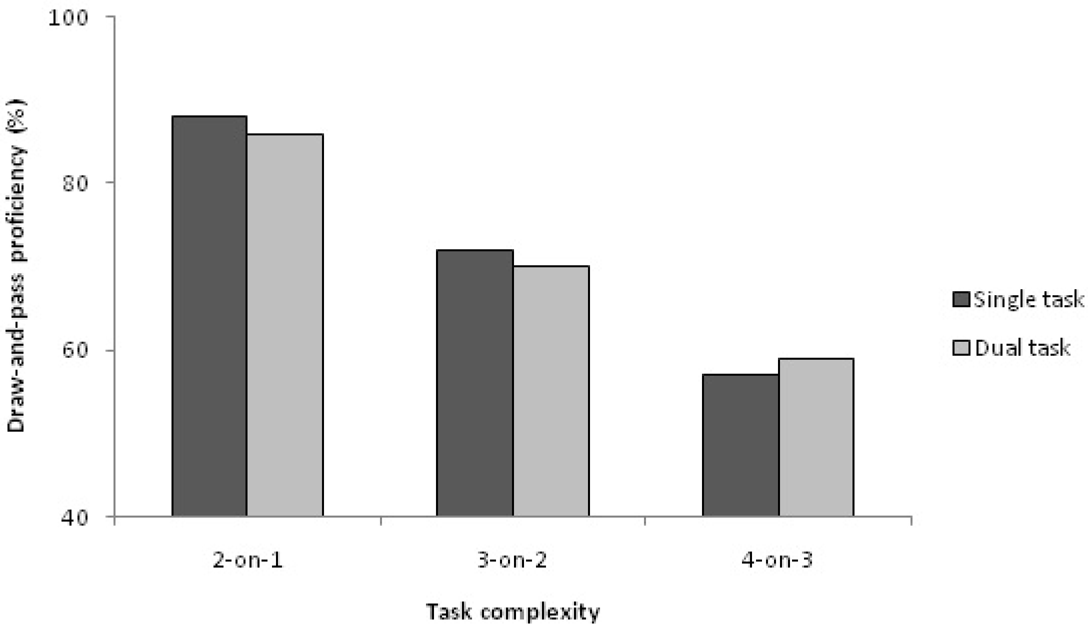
skilled vs. Highly-skilled) × 2 (condition – type of task: single vs. dual) × 3 (group – task complexity: 2-on-1 × 3-on-2 × 3-on-4) ANOVA. For the draw-and-pass performance task the ANOVA showed a significant effect of condition (single vs. dual) $F(1,26)=13.264$, $MSE=0.048$, $p<.001$, significant effect of group (task complexity), $F(2,26)=11.487$, $MSE=0.048$, $p<.037$, significant effect of condition by group (task complexity) by group (less-skilled vs. Highly-skilled) interaction, $F(2,26)=14.259$, $MSE=0.048$, $p<.003$. The effects of group (less-skilled vs. Highly-skilled), group (less-skilled vs. Highly-skilled) by condition interaction and group (task complexity) by group (less-skilled vs. Highly-skilled) interaction were not significant ($F<1$) (Figure 5).

Figure 5. Draw-and-pass (2-on-1, 3-on-2 and 3-on-4) proficiency of a) less-skilled rugby players and b) high-skilled professional rugby players under single task and dual task conditions.

a)



b)



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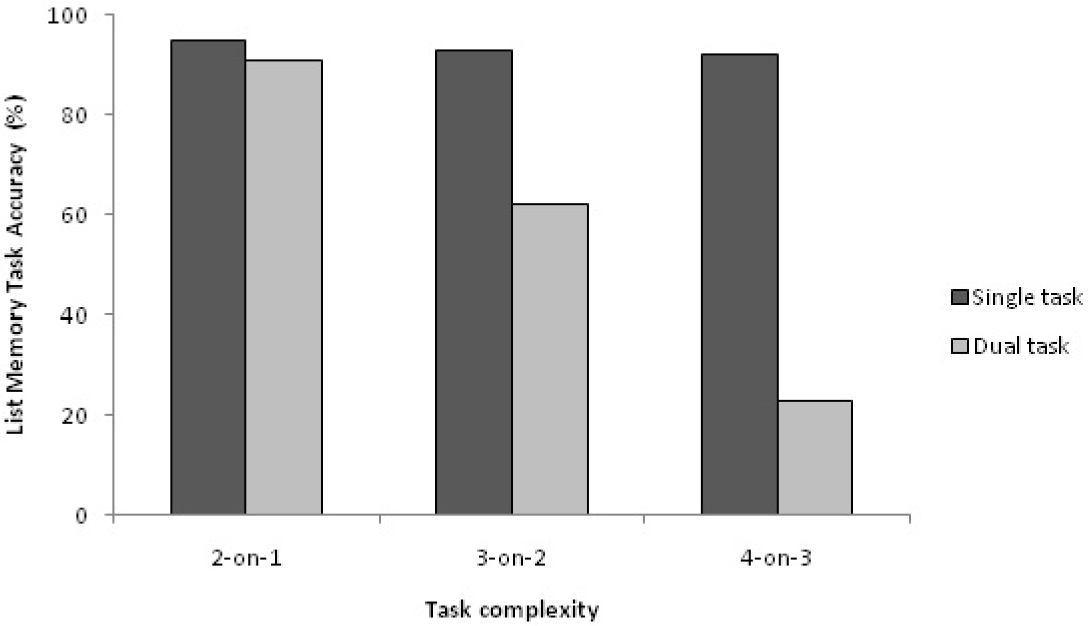
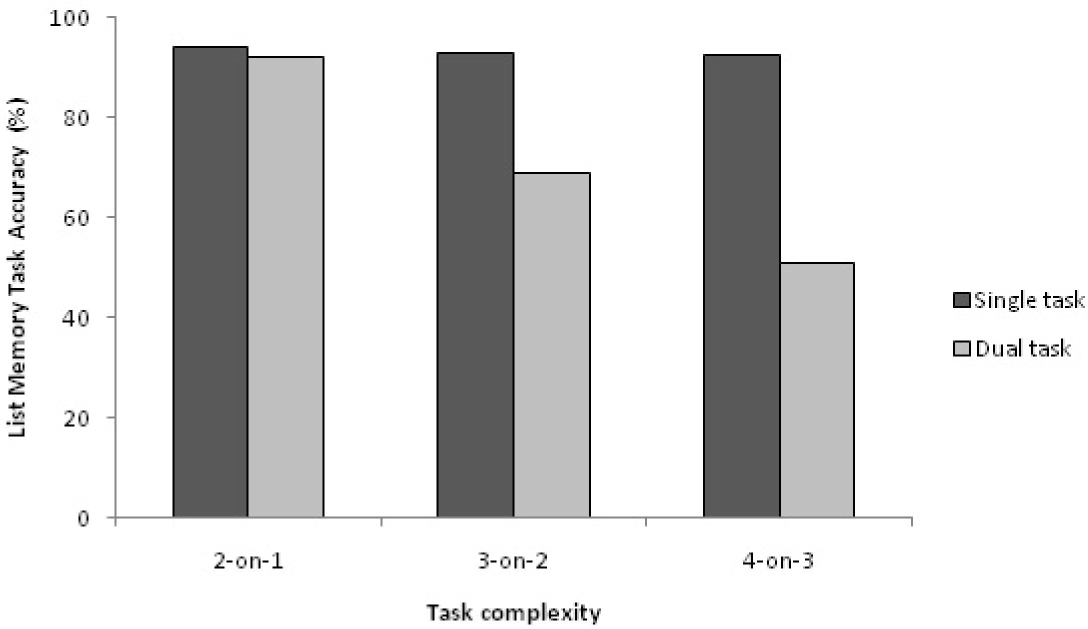
For the List Memory Task, the ANOVA showed a significant effect of condition (single vs. dual) F(1,26)=8.263, *MSE*=0.158, p<.021, significant effect of group (task complexity), F(2,26)=8.263, *MSE*=0.158, p<.007, significant effect of condition by group (task complexity) by group (less-skilled vs. Highly-skilled) interaction, F(2,26)=8.263, *MSE*=0.158, p<.013. The effects of group (less-skilled vs. Highly-skilled), group (less-skilled vs. Highly-skilled) by condition interaction and group (task complexity) by group (less-skilled vs. Highly-skilled) interaction were not significant (F<1) (Figure 6).

Figure 6. List Memory Task (2-on-1, 3-on-2 and 3-on-4) accuracy of a) less-skilled rugby players and b) high-skilled professional rugby players under single task and dual task conditions.

a)



b)



The relationships between paper and pencil dual-task (μ), working memory span task (WMS), single-task draw-and-pass performance (DPassST 2-on-1, DPassST 3-on-2, DPassST 4-on-3), off-field dual-task draw-and-pass performance (DPassDT 2-on-1, DPassDT 3-on-2, DPassDT 4-on-3)

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and competition draw-and-pass performance (2-on-1 Comp, 3-on-2 Comp, 4-on-3 Comp) for different levels of task complexity was assessed by the Pearson's product moment correlation coefficients**.**

Table 1. Relationship between paper and pencil dual task (μ), working memory span task (WMS), single-task draw-and-pass performance (DPassST 2-on-1, DPassST 3-on-2, DPassST 4-on-3), off-field dual-task draw-and-pass performance (DPassDT 2-on-1, DPassDT 3-on-2, DPassDT 4-on-3) and competition draw-and-pass performance (2-on-1 Comp, 3-on-2 Comp, 4-on-3 Comp) for different levels of task complexity**.**

	μ	**WMS**	**DPassST 2-on-1**	**DPassST 3-on-2**	**DPassST 4-on-3**	**DPassDT 2-on-1**	**DPassDT 3-on-2**	**DPassDT 4-on-3**	**2-on-1 Comp**	**3-on-2 Comp**	**4-on-3 Comp**
μ	1	-.11	.24	.13	.26	.33	.30(*)	.25(*)	.22(*)	.24(*)	.31(*)
WMS		1	.09	.11	.10	.18	.25	.35	.32	.28(*)	.37(*)
DPassST 2-on-1			1	.37(*)	.11(*)	.40(*)	.36(*)	.22(*)	.52(*)	.45(*)	.21(*)
DPassST 3-on-2				1	.13(*)	.17(*)	.25(*)	.12(*)	.28(*)	.27(*)	.14(*)
DPassST 4-on-3					1	.15(*)	.24(*)	.37(*)	.34(*)	.11	.25(*)
DPassDT 2-on-1						1	.36(*)	.48(*)	.42(*)	.29(*)	.19(*)
DPassDT 3-on-2							1	.45	.31(*)	.43(*)	.55
DPassDT 4-on-3								1	.22(*)	.49	.17(*)
2-on-1 Comp									1	.33(*)	.23(*)
3-on-2 Comp										1	.21
4-on-3 Comp											1

(*) denotes significance at $p<0.05$

Significant but moderate in strength relationships were found between WMS task score and competition draw-and-pass with 3-on-2 and 4-on-3 levels of task complexity $r=.28$, $p<.032$ and $r=.37$, $p<.011$ respectively. The paper and pencil dual-task (μ) was significantly correlated with off-field dual-task draw-and-pass performance with complexity levels of 2-on-1 and 4-on-3 and with competition draw-and-pass performance of all levels of task complexity. Significant correlations were not found between off-field single-task draw-and-pass performance with complexity level of 4-on-3 and competition draw-and-pass performance with complexity level of 3-on-2; between off-field dual-task draw-and-pass performances with complexity level of 3-on-2 and off-field dual-task draw-and-pass performances with complexity level of 4-on-3, also between off-field dual-task draw-and-pass performances with complexity level of 3-on-2 and competition draw-and-pass performance with complexity level of 4-on-3; between off-field dual-task draw-and-pass performances with complexity level of 4-on-3 and competition draw-and-pass performance with complexity level of 3-on-2. All other relationships between single- and dual-task draw-and-pass performances of off-field and competition conditions were significant but moderate in magnitude.

Discussion

Both less skilled and highly-skilled professional rugby players showed decrement in performance under dual task condition on paper and pencil version of dual task paradigm but study groups didn't differ in performance of the dual task paradigm in some specific way.

For both List Memory Task and draw-and-pass performance task was shown decrement in performance under dual task condition for both study groups.

Study found significant effect of increase of task complexity for both study groups namely 4-on-3 draw-and-pass performance was worth than 3-on-2 draw-and-pass performance and the last was performed worth than 2-on-1 draw-and-pass performance for both less skilled and highly-skilled professional rugby players. It was found significant differential effect of increase of task complexity on dual-task draw-and-pass performance for less skilled and highly-skilled professional rugby players - highly-skilled professional rugby players performed better on dual-task 4-on-3 draw-and-pass task than less skilled rugby players.

For the List Memory Task was found significant effect of increase of task complexity on performance of the List Memory Task for both study groups namely of the List Memory Task performance in coordination with 4-on-3 draw-and-pass performance was worth than in coordination with 3-on-2 draw-and-pass performance and the last was performed worth than in coordination with 2-on-1 draw-and-pass performance for both less skilled and highly-skilled professional rugby players. Similarly was found significant differential effect of increase of task complexity on dual-task for the List Memory Task performance for less skilled and highly-skilled professional rugby players - highly-skilled professional rugby players showed less decrement in task performance under dual-task 4-on-3 draw-and-pass task than less skilled rugby players. This suggests that highly-skilled professional rugby players have more automated dual-task coordination ability than less skilled rugby players.

Reduction of performance for motor and auditory tasks in both single and dual task conditions when task complexity was increased shows greater attentional demands required for conduction of complex single and dual tasks as was shown in previous studies [17, 18]. The less decrement in performance under the most complex dual-task 4-on-3 draw-and-pass task for highly-skilled professional rugby players in comparison of less skilled rugby players suggests higher ability of highly-skilled professional athletes of better ability of two tasks' coordination and it rises important suggestion that dual-task ability can be trained by sport exercises as was shown in previous studies [17] but needs further research and validation.

Relatively low in magnitude correlation coefficients may reflect specificity of competitive skills in comparison to off-field draw-and-pass skills and also contribution of other factors not taken into account in the preset study.

Significant but moderate in strength correlations between WMS task score and competition draw-and-pass with 3-on-2 and 4-on-3 levels of task complexity may show necessity of high general working memory capacity in complex tasks performance under the increased pressure of competition to respond properly to complex real competition situation where high attentional and working memory demands are presented. The same results were found for less skilled and expert athletes with higher magnitude correlation coefficient for expert athletes that may be explained by better use of working memory capacity by expert athletes in complex real competition situation than by less skilled rugby players.

The significant correlation between paper and pencil dual-task (μ) and off-field dual-task draw-and-pass performance with complexity levels of 2-on-1 and 4-on-3 and with competition draw-and-pass performance of all levels of task complexity indicates that laboratory off-field dual task method in some extent can be used in prediction of off-field draw-and-pass dual task and competitive draw-and-pass performances as was suggested in other studies using different tasks [22-26]. According to study results the paper and pencil dual-task method can be used in differential diagnostics of athletes' abilities. This result also suggests that the same two tasks coordination ability reveals itself in two different settings and it represents the same central executive function. The results didn't differ for less skilled and expert athletes.

The off-field dual-task draw-and-pass 2-on-1 performance significantly predicts all single and dual-task draw-and-pass performances for all studied task complexity levels that shows importance of off-field dual-task draw-and-pass 2-on-1performance in prediction of on-field real game competition performance and that this task can be used and standardized for prediction of successful on-field performance of rugby players. The off-field dual-task draw-and-pass 3-on-2 and 4-on-3 performances were not correlated with all on-field dual-task draw-and-pass performance and magnitude of the revealed correlations were much less than correlations found for the off-field dual-task draw-and-pass 2-on-1 performance thus priority in prediction of on-field competition performance can be devoted to the off-field dual-task draw-and-pass 2-on-1 performance. Small but significant correlation between off-field dual-task draw-and-pass 2-on-1 performance and competition 4-on-3 performance may reflect dependence and greater contribution of the last on other skills different from off-field dual-task draw-and-pass 2-on-1 performance.

Future research is warranted to standardized off-field dual-task draw-and-pass 2-on-1 performance procedure as a predictor task of individual athlete's on-field completion performance. It is needed to determine if the dual-task coordination ability of draw-and-pass 2-on-1 performance can be trained in rugby players; determine training intensity, conditions and procedure that will lead to automaticity of performance; determine factors of reaching dual-task draw-and-pass 2-on-1 performance automaticity level necessary for successful competition draw-and-pass attempts leading to tries.

Conclusion

In conclusion decrement in performance under dual task condition on paper and pencil version of dual task paradigm and of the List Memory Task and draw-and-pass task was shown by both study groups. The significant effect of increased task complexity was found for both study groups. The study revealed significant differential effect of increase of task complexity on dual-task draw-and-pass and the List Memory Task performance for less skilled and highly-skilled professional rugby players that suggests possessing of higher ability of automated performance of motor skills by professional athletes and strongest resilience of motor skills' performance under complex conditions of real sport competition. It can be suggested that dual-task ability can show level of proficiency of athletes and can be trained by sport exercises for qualification improvement. According to the study the general working memory capacity may be necessary for the high performance under the increased pressure of competition in complex real competition situations where high attentional and working memory demands are required. The laboratory off-field dual task method in some extent can be used in prediction of off-field draw-and-pass dual task and competitive draw-and-pass performances. The paper and pencil dual-task method can be used in differential diagnostics of athletes' abilities. The off-field dual-task draw-and-pass 2-on-1 performance significantly predicts on-field real game competition performance and that this task can be used and standardized for prediction of successful on-field performance of rugby players.

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The article includes 9 figures and 1 table.

Article received 2018-08-21