A Duel Between Cognitive and Physical Performance: Who Wins- The Brain or Body?

Submitted to the Faculty of Arts

In Partial Fulfillment of the Requirements

For the Degree of

Bachelor of Arts Honours

in

Psychology

University of Regina

By

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April 29, 2019
# A Duel Between Cognitive and Physical Performance: Who Wins—The Brain or Body?

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Abstract

When a motor and cognitive task are performed simultaneously, the brain and the muscles must compete for the same resources (e.g., energy, etc.) which is known as *interference*. The selfish brain hypothesis (Peters et al., 2004) suggests the brain prioritizes its own glucose needs over those of the peripheral organs such as skeletal muscle. It is still unclear the impact this interference has on cognitive and/or physical performance. The purpose of this study was to investigate the selfish brain hypothesis and examine how explicit prioritization affects allocation of resources and dual task performance. Using a between subjects research design, 32 participants were randomly assigned to a no priority, cognitive priority, or physical priority group. The NeuroTracker, a perceptual cognitive training program and cycle ergometer were used to measure cognition and physical performance, respectively. Participants completed 5 assessments: 2 cognitive, 1 predicted VO$_2$ max, and 1 dual task. During the dual task participants completed 3 NeuroTracker sessions, while cycling on a cycle ergometer. One-way ANOVA’s and tukey post hoc tests revealed the physical priority group had significantly higher RPMs at the 8 second time points compared to the cognitive priority group. However, when comparing RPMs and visual tracking speed scores across all three groups, physical performance remained relatively stable throughout the physical and dual task assessments. All groups experienced improvements in their visual tracking speed scores as they progressed through the study. We suggest the assessments prior to the dual task acted as training sessions and therefore, limited dual task interference.
Acknowledgements

It is a pleasure to thank all those who in many ways contributed and offered their valuable assistance in the preparation and completion of this study and thesis. I am indebted to my Honours supervisor Dr. Kim Dorsch who gave me the opportunity to conduct my research through both the Faculty of Psychology and Kinesiology. Her continuous support, patience, encouragement and expertise knowledge assisted me in successfully completing this thesis. I am grateful for all the work James Bradshaw our personal trainer for the study has put in over this semester. The success of this study would not have been possible without his help. A very special thank you goes out to Barclay Dahlstrom who time and time again helped us design the physical component of our study. I want to thank Rob McCaffrey for his time spent teaching me how to use the equipment and continuous support throughout the term. A thank you goes out to Dr. Harold Reimer for allowing me recruit through his Kinesiology course. I must also acknowledge Dr. Donald Sharpe, who helped us through data analysis. It was an unforgettable journey towards my undergraduate Bachelor of Arts (Honours) Degree. I am forever grateful for the array of help I received from so many. Thank you again to all those who have helped make this thesis possible.
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*Dual tasks* are characterized by the simultaneous performance of two tasks that can be performed independently and have distinct and separate goals. *Dual task interference* occurs when two tasks are carried out at the same time and require the same resources. However, when the resources become limited, processes carrying out the two tasks must compete for what both need, and interference occurs (Navon & Miller, 1986). As a result of the interference, performance in one or both tasks can decline, or task performance may exhibit a trade off so the performance of one task can be improved only at the expense of the other task (Navon & Miller, 1986).

Dual task research involving a motor and cognitive task results in competition for glucose and attentional resources. However, the impact this interference has on performance is still unclear despite the in-depth research already conducted. Schaefer, Krampe, Lindenberger, and Baltes (2008) found children who balanced on an ankle disc board while performing a cognitive task measuring working and episodic memory showed performance decrements only in the cognitive task. Moreover, children showed improvements in the balance task, suggesting they allocated more resources into the balancing task to preserve their safety. Additionally, adults demonstrated performance decrements in both tasks under the same dual task conditions. Similarly, Bernard-Demanze, Dumitrescu, Jimeno, Borel, and Lacour (2009) found a difference in how younger and older adults prioritized two tasks. When younger adults shifted their attention away from the postural task, they improved their postural performance. However, older adults only showed improvements in postural control when they focused on their postural performance. Older adults prioritized posture control by investing their cognitive resources into monitoring stability and avoiding falls.
Resch, May, Tomporowski, and Ferrara (2011) discovered supporting evidence for the posture first principle in which a trade off would occur where balance would be maintained at the expense of cognitive function. Therefore, they suggested that posture control is attentionally demanding requiring increased allocation of attentional resources in accordance with the complexity of the postural task. However, more recently Fabri et al. (2017) observed that postural stability decreased under dual task conditions, while performance in a cognitive attention task was maintained or improved. Attention took precedence over postural control when performing the tasks simultaneously.

There is much inconsistency regarding the effects dual tasks have on physical and cognitive performance. A potential reason for this inconsistency may be related to the physical task, in which balance becomes a threat to individuals. To avoid inconsistent finding researchers also conducted studies in which balance would be less of a threat to participants’ performance outcomes. In 2010, Schaefer, Lövdén, Wieckhorst, and Lindenberger investigated how 9-year olds and young adults performed a working memory task while walking on a tread mill. Young adults stride lengths and stride time variability decreased with cognitive load whereas children showed an increase in walking variability when cognitive load increased. Participants in both age groups showed improvements in cognitive performance when walking at a preferred speed as opposed to walking at a fixed non-preferred speed. These researchers concluded that the interaction of walking and cognitive performance is influenced by sharing resources between two tasks and that performance improvements in cognition may be caused by an exercise induced activation of resources. Most recently, Longman, Stock, and Wells (2017) conducted a study investigating a trade off involving the brain and muscles. Mental performance was measured by a free recall test and physical performance was measured by power output on a rowing
ergometer. The mental and physical tasks were performed in isolation and again simultaneously. They found that both power output and mental performance decreased when performed together. However, the decrease in the physical was greater than the decrease in the mental. Their study supported the *selfish brain hypothesis* (Peters et al., 2004 as cited in Longman et al. 2017) in which the brain prioritizes its own glucose needs over those of the peripheral organs such as skeletal muscle. Although Longman et al. (2017) found support for the selfish brain hypothesis they did not examine how task prioritization impacted how the brain and body prioritized and distributed their resources during dual tasks. However, Yogev-Seligmann et al. (2010) investigated how task prioritization impacted motor and cognitive performance using walking and verbal fluency tasks, respectively. Participants were young and old adults who completed a motor walking task on solid ground while simultaneously performing a cognitive verbal fluency task under three separate instruction conditions: No specific prioritization, prioritization of gait, and prioritization of the cognitive task. When asked to prioritize gait, the young adults significantly increased their gait speed. When asked to prioritize the cognitive task, gait speed decreased among both age groups. Gait speed reduced in both young and older adults when no instructions were given, suggesting cortical function influenced gait. Additionally, the authors suggested older adults may have a reduced ability to prioritize and flexibly allocate their attentional resources since they only showed small changes in gait speed during all 3 instruction tasks. However, it may also be that older individuals did not significantly increase their gait speed because they saw the motor task as a threat to their balance and chose to protect themselves from falling.

Based on previous dual task research there are inconsistent findings regarding the effects dual tasks have on physical and cognitive performance and how individuals allocate their
resources. There is limited empirical evidence focusing on the selfish brain hypothesis, and the mechanisms it entails. Additional research is needed to clarify these effects, especially when balance is not a threat to participants and investigate the trade off between the brain and muscles during dual tasks. The aim of this research is to address gaps in the literature regarding dual task interference and the effects it has on dual task performance. Furthermore, this research examines participants’ allocation of resources and the effects of explicit attentional directions on performance in concurrent cognitive (i.e., NeuroTracker) and motor (i.e., cycle ergometer) tasks. By using the three-dimensional multiple object tracking and a cycle ergometer we introduce a new technique for experimentally investigating the trade off between the brain and muscles during dual tasks. A between-subjects research design was used to examine three hypotheses: (1) Participants in the no priority group would prioritize the cognitive task over the physical task therefore, physical decline would exceed cognitive decline. (2) the cognitive priority group would prioritize the cognitive task over the physical task, physical decline would exceed cognitive decline. (3) The physical priority group would prioritize the physical task over the cognitive task, cognitive decline would exceed physical decline. By using the cycle ergometer, we did not expect participants to view the physical task as a threat to balance.

**Method**

**Participants**

Thirty-nine healthy young adults from the University of Regina completed all 5 assessments of this study. Seven participants were removed from data analysis as their cognitive scores indicated they were outliers. The final sample size was thirty-two young adults (25 women, 7 men) with a $M$ age of 20.97, ($SD = 2.48$) years. Criteria for participating included being between the ages of 17 and 26, and an absence of color vision deficiencies, concussion,
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diagnosis of epilepsy, attention deficit hyperactivity disorder (ADHD), or attention deficit disorder (ADD). Additionally, any participants who indicated on the Get Active Questionnaire (“Pre-Screening for Physical Activity Participation,” n.d.) that they had a physical injury or were instructed by a health care professional not to take part in physical activity were excluded from this study (see description below). Participants were recruited through the University of Regina Psychology Participant Pool and a second year Kinesiology course.

Procedure

After obtaining approval from the University of Regina Research Ethics Board, Regina, Saskatchewan, Canada (see Appendix A), a consent form (see Appendix B), demographic (see Appendix C), and Get Active Questionnaires (see Appendix D) were emailed out to individuals who expressed interest in the study. Eligible participants who provided consent were randomly assigned to one of three groups: Control (no prioritization), treatment (cognitive prioritization), or treatment (physical prioritization). After providing written informed consent all participants completed 5 assessments of 4 separate days: Two single cognitive, predicted VO₂ Max, physical and dual task assessment. All data were collected at the University of Regina in the Motivation for Active Living Laboratory.

Measures

Demographics. A demographic questionnaire was used to gather information about the participants’ age, and sex, and was used to screen participants who self-identified as having a colour vision deficiency, epilepsy, ADD or ADHD. A demographic screening questionnaire was used to gather information about the participants’ physical activity levels, participation in sport, number of hours of sleep they had the night before, and type of beverages consumed in the last four hours. Additionally, participants identified if they wore glasses, or had eye surgery.
Get Active Questionnaire (“Pre-Screening for Physical Activity Participation,” n.d.). This self-report questionnaire was used to evaluate physical symptoms that could prevent individuals from safely engaging in physical activity. Items included in this measure were cardiac problems, high blood pressure, injury, concussion, diabetes, cancer, osteoporosis, asthma, spinal cord injuries, pain and swelling, aspiration problems, loss of consciousness, and dizziness. Participants who identified as experiencing any of these problems in the last 6 months had to have a physician’s clearance before partaking in the study. Participants who did not identify as experiencing any of these problems were eligible to participate.

Assessments

Single task cognitive assessment. Participants completed three single task cognitive assessments on two separate days to become familiar with the NeuroTracker task. During this assessment participants were seated in front of a three-dimensional television (NeuroTracker) wearing three-dimensional glasses. As described below, participants were instructed to track target balls on the screen and complete three sessions (60 trials) on the NeuroTracker. During the trials participants verbally indicated their answers to the researcher who sat beside them recording and inputting their answers into the NeuroTracker system.

NeuroTracker. The three-dimensional multiple object tracking (NeuroTracker) is a perceptual cognitive training program. The cognitive functions engaged in NeuroTracker are theorized to be attention, working memory, and visual information processing speeds. Visual tracking speed (VTS) in a three-dimensional environment was used as a measure of cognitive-perceptual performance (Parsons et al., 2016). Researchers have identified baseline VTS scores for healthy participants to be around 0.97 and 1.0. (Faubert, 2013; Legault, Allard, & Faubert, 2013). During this session participants were seated in front of a three-dimensional television wearing three-
dimensional glasses. The NeuroTracker program initially presents eight yellow balls in 3-D space. Subsequently four balls were identified with an orange halo with the other four remaining yellow (Fig. 1a). After two seconds, the balls all revert to yellow and move around the screen at a speed of 30.48 cm/s for eight seconds (Fig. 1b). After the eight seconds the balls stop in their place on the screen and a number appears on all eight balls (Fig. 1c). The participants are then asked to identify which balls were the original four orange balls which the researcher inputs. Participants are immediately given feedback as to the number of balls they identified correctly. If the participant correctly identifies all four balls, the task becomes more difficult and the balls move around the screen faster in the next trial. If the participant incorrectly identifies even one ball, the task becomes less difficult, and the balls move around the screen slower in the next trial. The trials are repeated 20 times for one session and three sessions were completed in one sitting (60 trials). The cognitive assessment took 23-24 minutes to complete. At the end of the cognitive assessment the NeuroTracker identified the participants overall visual tracking speed score. The VTS score has been shown to be a valid indicator of the quality of high-brain cognitive function (Fabri et al., 2017; Romeas, Guldner, & Faubert, 2016).

Figure 1. Depiction of the Cognitive Assessment (NeuroTracker) Task.
Predicted VO₂ max assessment. On the third day participants completed the single task cognitive assessment, and then were given a 10-minute break before beginning the YMCA cycle ergometer test (Beekley et al., 2004). The cycle ergometer test was performed under the supervision of a certified personal trainer. It uses three or more consecutive three-minute workloads designed to raise heart rate to between 110 beats per minute (bpm) and 85% of age predicted heart rate max for two consecutive loads. During this test the cycle ergometer’s first workload was set at 150 kpm/min and the participant was instructed to begin pedalling at a rate of 50 revolutions per minute (RPMs) for three minutes. The participant’s heart rate was recorded during the final 15 seconds of each minute. The heart rate during the last minute of the first workload determined the load sequence for the concurrent workload periods. The workload continued to increase until the participant’s steady-state heart rate was within 10 bpm of the 85% predicted heart rate maximum (Beekley et al., 2004). Age adjusted heart rate maximum was determined using the following formula Heart Rate =0.85 × [(220-age)] (Tanaka, Monahan & Seals, 2001). The information gathered from this task was used to provide the researcher with the participants' predicted VO₂ max which was used during the physical and dual task assessments.

Physical Assessment. During this assessment, the ergometer screen was covered to control for distractions. Participants first cycled on the cycle ergometer for three minutes at a comfortable pace. After the three minutes participants were instructed to pedal at 70 RPMs with the resistance set to 60% of their predicted VO₂ max for 23 minutes (the same amount of time it took them to complete the single task cognitive assessment). Participants’ RPMs were recorded every 8 and 13 seconds for the full 23 minutes. The reason we chose to document RPMs at 8 seconds was to match the same amount of time the balls moved around the screen during the
single task cognitive assessment, and it took an additional 13 seconds after the balls stopped for participants to answer and the next trial to begin.

**Dual task assessment.** During the dual task assessment, a cycle ergometer was placed in front of the NeuroTracker, with the ergometer screen covered. Participants were given a 3-minute warm up and then were given a specific set of instructions depending on the priority group they were assigned to. The dual task required all participants to complete 60 trials on the NeuroTracker while pedalling at 70 RPMs with the resistance set at 60% of their predicted VO2 max. The reason for choosing 60% is based on research done by the National Council on Strength and Fitness in which the pace would be between a slow and steady run. The general instructions for all three groups was “perform both tasks (cognitive and physical) as well as you can.” The control group (Group 1) was given no instructions on which task to prioritize. The cognitive priority group (Group 2) was instructed to prioritize the NeuroTracker task, and the physical priority group (Group 3) was instructed to prioritize the physical task. RPMs were recorded every 8 and 13 seconds to match the physical assessment protocol. All three groups were given cognitive and physical feedback at the end of each trial. The NeuroTracker displayed their VTS scores and the researcher verbally indicated their RPMs produced at the 8 second time points. Throughout the 60 trials RPMs were recorded every 8 and 13 seconds.

**Results**

The Statistical Package for the Social Sciences (SPSS) software was used to complete the data analyses. Seven participants were removed from the final data analyses as these participants had abnormal NeuroTracker scores. Four participants had previous experience training with NeuroTracker and displayed relatively high scores at baseline. These scores continued to increase and skewed the data. The other two participants had extremely low VTS scores at
baseline and again during the final assessment, suggesting they struggled with the cognitive task. We chose to remove their scores as they too skewed the data. The independent variable for this study was task prioritization, while the dependent variables were cognitive perceptual performance (VTS), and RPMs.

**Descriptive statistics**

Descriptive statistics were performed on age, RPMs and NeuroTracker scores, (see Tables 1 and 2 and 3 respectively).

Table 1

*Participant Characteristics*

<table>
<thead>
<tr>
<th>Variable</th>
<th>Young Adults (n=32)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (y)</td>
<td>20.97±2.48</td>
</tr>
<tr>
<td>Regular Participation in PA</td>
<td>24 PP</td>
</tr>
<tr>
<td>No Regular Participation in PA</td>
<td>8 PP</td>
</tr>
<tr>
<td>Recreational Sport Participation</td>
<td>18 PP</td>
</tr>
<tr>
<td>Competitive Sport Participation</td>
<td>6 PP</td>
</tr>
</tbody>
</table>

PA= Physical Activity; PP= Participants

Table 2

*Average RPM Differences During Physical and Dual Task Assessments*

<table>
<thead>
<tr>
<th>Average RPM Differences</th>
<th>Group 1</th>
<th>Group 2</th>
<th>Group 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>P-RPM at 8 sec</td>
<td>70.20</td>
<td>69.63</td>
<td>70.92</td>
</tr>
<tr>
<td>P-RPM at 13 sec</td>
<td>70.15</td>
<td>69.41</td>
<td>70.82</td>
</tr>
<tr>
<td>D-RPM at 8 sec</td>
<td>70.02</td>
<td>68.29</td>
<td>71.52</td>
</tr>
<tr>
<td>D-RPM at 13 sec</td>
<td>69.73</td>
<td>68.63</td>
<td>71.28</td>
</tr>
</tbody>
</table>

P-RPM= Physical Assessment RPM; D-RPM=Dual Task Assessment RPM
Table 3

<table>
<thead>
<tr>
<th>Average VTS Differences During Dual Task Assessment</th>
<th>Group 1</th>
<th>Group 2</th>
<th>Group 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>NT- SNGL Assessment 1</td>
<td>1.28</td>
<td>1.47</td>
<td>1.37</td>
</tr>
<tr>
<td>NT- SNGL Assessment 2</td>
<td>1.39</td>
<td>1.63</td>
<td>1.41</td>
</tr>
<tr>
<td>NT-DT Assessment 3</td>
<td>1.46</td>
<td>1.70</td>
<td>1.52</td>
</tr>
</tbody>
</table>

NT-SNGL = NeuroTracker Single Task Assessment; NT-DT = NeuroTracker Dual Task Assessment

Hypotheses testing

Three one-way analyses of variance (ANOVAs) with 3 groups in each and Tukey post-hoc tests were used to test for differences in motor and cognitive performances among priority groups. A one-way ANOVA testing the differences between the mean RPMs at 8 seconds during the dual task was statistically significant, $F(2,29) = 3.24$, $p < .050$, $\eta^2_p = .183$. Tukey post-hoc tests ($p < .05$) revealed that Group 3 (physical priority) ($M = 71.52$, $SD =2.05$) had significantly higher RPMs during the 8 second time points than Group 2 (cognitive priority) ($M = 68.29$, $SD =4.61$). This suggests participants in the physical priority group successfully prioritized the physical task. However, a mean score of 68.29 RPMs for the cognitive group suggests this group prioritized the cognitive task over the physical. However, they did not experience interference, as their RPM’s remained consistent across the physical and dual task assessments.
Table 4

Tukey Post Hoc Tests for Dual Task NeuroTracker Scores, and Average RPMs at 8 and 13 Seconds.

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>Group (I)</th>
<th>Group (J)</th>
<th>Mean Difference (I-J)</th>
<th>Std. Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>DN Score</td>
<td>1.00</td>
<td>2.00</td>
<td>-.23300</td>
<td>.11672</td>
</tr>
<tr>
<td></td>
<td>3.00</td>
<td>2.00</td>
<td>.06133</td>
<td>.11175</td>
</tr>
<tr>
<td></td>
<td>3.00</td>
<td>1.00</td>
<td>.23300</td>
<td>.11175</td>
</tr>
<tr>
<td></td>
<td>3.00</td>
<td>2.00</td>
<td>.17167</td>
<td>.11175</td>
</tr>
<tr>
<td>DT RPM 8</td>
<td>1.00</td>
<td>2.00</td>
<td>1.72900</td>
<td>1.32557</td>
</tr>
<tr>
<td></td>
<td>3.00</td>
<td>2.00</td>
<td>-1.50233</td>
<td>1.26914</td>
</tr>
<tr>
<td></td>
<td>3.00</td>
<td>1.00</td>
<td>-3.23133*</td>
<td>1.26914</td>
</tr>
<tr>
<td></td>
<td>3.00</td>
<td>2.00</td>
<td>3.23133*</td>
<td>1.26914</td>
</tr>
<tr>
<td>DT RPM 13</td>
<td>1.00</td>
<td>2.00</td>
<td>-1.06600</td>
<td>1.24777</td>
</tr>
<tr>
<td></td>
<td>3.00</td>
<td>2.00</td>
<td>-1.55233</td>
<td>1.19465</td>
</tr>
<tr>
<td></td>
<td>3.00</td>
<td>1.00</td>
<td>1.55233</td>
<td>1.19465</td>
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<tr>
<td></td>
<td>2.00</td>
<td>3.00</td>
<td>2.61833</td>
<td>1.19465</td>
</tr>
</tbody>
</table>
* The mean difference is significant at the 0.05 level.

DN Score = Dual Task NeuroTracker Score (VTS); DT RPM 8 = Dual Task RPM at 8 seconds; DT RPM 13 = Dual Task RPM at 13 seconds

Discussion

The primary aim of this study was to examine how explicit and no prioritization impacts dual task performance and allocation of resources to the brain and/or body. Furthermore, this is one of few studies in which we have controlled for individual fitness levels and adapted our equipment so balance would not be a threat and confound the results. Previous researchers (Resch et al., 2011; Schaefer et al., 2008; Yogev-Seligmann et., 2010) have chosen to use walking or balancing tasks to measure motor performance during a dual task. However, the use of treadmills or balance boards are attentionally demanding as these tasks threaten balance, resulting in increased allocation of resources towards the physical task. In this study we chose to control for balance by using the cycle ergometer which allowed participants to hold onto handle bars and perform the motor task in a sitting position.
We proposed explicit prioritization of a task would result in a trade off in which participants would experience improvements in the task they were told to prioritize and decrements in the non prioritized task. Additionally, participants in the no priority group would prioritize the cognitive task over the physical and therefore, we would find support for the selfish brain hypothesis (Peters et al., 2004). However, inconsistent with earlier dual task literature, our study found no support for the selfish brain hypothesis, or dual task interference. Consistent with findings such as Yogev-Seligmann et al. (2010) we observed significant differences in motor performance between the cognitive priority and physical priority groups. Participants who were instructed to prioritize the physical task had significantly higher RPMs during the 8 second time points than those instructed to prioritize the cognitive task (Table 2). However, when comparing each groups average RPMs at baseline and again during the dual task, motor performance remained relatively stable with minimal improvements of decrements (Table 2). Furthermore, the cognitive priority group produced the lowest RPMs on average at both the 8 and 13 second time points. The no priority group’s cycling speed during the dual task remained relatively similar to their baseline performance. This finding is inconsistent with Yogev-Seligmann et al. (2010) who observed a decrease in gait speed when no instructions on task prioritization were given.

We were unable to demonstrate with significance how explicit prioritization of a physical or cognitive task impacted physical and cognitive performance. Although explicit prioritization did not have an impact on dual task performance, all three groups demonstrated increases in their VTS scores as they progressed through the two-single cognitive and dual task assessments (9 training sessions) over a 2-3-week period (Table 3). This finding is explained using Parsons et al. (2016) research suggesting a learning curve occurs when using the NeuroTracker. In their study participants demonstrated significant improvements in their VTS scores over a 5-week period.
where they completed 10 training session. Based on the literature we suggest improvements in cognitive functioning during the dual task may have been due to the learning curve associated with NeuroTracker.

Dual tasking requires coordination of two tasks usually resulting in interference in the form of a trade off between the brain and body (Navon & Miller, 1986). A potential reason we found an absence of dual task interference across the three groups may have been that since participants were all healthy young adults, they already had the optimal cognitive and physical capacities to handle the challenging dual task conditions without experiencing performance decrements. Additionally, 24 of our participants regularly participated in physical activity and sport therefore, perhaps the physical task was not demanding enough for participants and therefore, the brain and body did not have to compete for resources. Another suggestion for not finding interference could have been that the pre-dual-task assessments acted as training sessions which helped participants allocate their resources equally to perform optimally during the dual task. This may be why we found minimal changes in motor and cognitive performance among all groups during the dual task. These results challenge Pellecchia’s (2005) findings which suggested dual task practice, not single task practice, improved dual-task performance. Future research is needed to compare these two training sessions with larger sample sizes.

Our research has implications for the sport and cognitive psychology fields of research. Understanding how athletes allocate their resources during dual task training can help athletes identify areas they need improvements in such as, increased training in the physical task if physical performance decline exceeds cognitive decline. From here we suggest single task training sessions have the potential as being an effective strategy in reducing and potentially eliminating dual task interference among both athletic and non athletic individuals. Eliminating
dual task interference in a lab setting may result in reduced dual task interference on the field and lead to improved sport performance. Within the domains of cognitive psychology our research challenges and contradicts previous dual task research and suggests controlling for personal fitness levels is essential in conducting future research. We also propose dual task interference can be eliminated using training sessions.

**Limitations and Future Research**

This study has several limitations. The number of participants who successfully completed all the assessments was small, and this factor may have affected the findings. Additionally, since we conducted a between-subjects research design it was impossible to maintain homogeneity in VTS scores and RPMs across all three groups therefore, differences in performances could potentially be due to group differences. Furthermore, our study design involved the researcher being in the same room as the participants during their assessments, which may have caused participants to feel anxious or stressed, potentially confounding results. Another potential limitation mentioned earlier was the physical component of the study. Perhaps the physical task of cycling at 60% of predicted VO₂ max was not demanding enough for these young adults, which may explain why we did not notice large differences in motor performance during the dual task. Additionally, we chose to conduct a predicted VO₂ max rather than an actual VO₂ max based on the equipment that was available to us. The predicted VO₂ is not as accurate as the VO₂, meaning participants cycled at an easier resistance than if they had done the VO₂.

Previous researchers have found support for interference occurring during a dual task. However, our study contradicts this, therefore, more research is needed to clarify the effects dual tasks have on performance while controlling for physical activity levels using the actual VO₂.
protocol. Moreover, future research should be directed at examining whether different levels of mentally and physically demanding tasks impact the amount of dual task interference that may occur. Additionally, as noted earlier we believe the assessments prior to the dual task acted as training sessions, therefore more investigation is needed to determine if and how effective training sessions are in reducing and potentially eliminating dual task interference.

**Conclusion**

This study demonstrated that using the NeuroTracker and cycle ergometer simultaneously was an effective way to study dual task performance. We found no support for dual task interference or a trade off between the brain and body. Instead, average VTS scores during the dual task increased from baseline among all three priority groups. Furthermore, motor performance remained relatively stable for all three groups when comparing the single task physical assessment and dual task assessment. All groups were able to perform at optimal physical and cognitive levels during the dual task, suggesting both the brain and body won. We were unable to determine how explicit prioritization of a physical or cognitive task during the dual task enhanced performance. We suggest a potential reason we found no dual task interference may be that the pre-dual-task assessments acted as training sessions which helped participants allocate their resources equally to perform optimally during the dual task. However, this area of study needs further investigation to determine the extent training sessions act in minimizing dual task interference. Lastly, we propose our findings have implications in both sport and cognitive psychology fields.

**References**


Faubert, J. (2013). Professional athletes have extraordinary skills for rapidly learning complex and neutral dynamic visual scenes. *Scientific Reports, 3*, 1154. doi :10.1038/srep01154


Appendix A

Research Ethics Board Certificate of Approval

The University of Regina Research Ethics Board has reviewed the above-named research project. The proposal was found to be acceptable on ethical grounds. The principal investigator has the responsibility for any other administrative or regulatory approvals that may pertain to this research project, and for ensuring that the authorized research is carried out according to the conditions outlined in the original protocol submitted for ethics review. This Certificate of Approval is valid for the above time period provided there is no change in experimental protocol, or related documents.

Any significant changes to your proposed method, procedures or related documents should be reported to the Chair for Research Ethics Board consideration in advance of its implementation.

ONGOING REVIEW REQUIREMENTS
In order to receive annual renewal, a status report must be submitted to the REB Chair for Board consideration within one month of the current expiry date each year the study remains open, and upon study completion. Please refer to the following website for the renewal and closure forms:
https://www.uregina.ca/research/for-faculty-staff/ethics-compliance/human/ethicsforms.html

Laurie Chune PhD
REB Chair
University of Regina
Appendix B

Participant Consent Form

Project Title: A Duel Between Cognitive and Physical Performance: Who wins- The Brain or Body?

Researcher(s): Berkley Petersen, Primary Investigator, Psychology Honours Student, Faculty Arts, University of Regina, 306 354-7256, peterber@uregina.ca

Dr. Kim Dorsch, Honours Supervisor, Faculty of Kinesiology and Health Studies, University of Regina, 306-585-4742, kim.dorsch@uregina.ca

Rob McCaffrey, Research Assistant, Ph.D. candidate, Faculty of Kinesiology and Health Studies, University of Regina, 306-337-8487, rob.mccaffrey@uregina.ca

Erin Harris, Research Assistant, Ph.D. student, Faculty of Kinesiology and Health Studies, University of Regina, 306-337-8487, erin.harris@uregina.ca

Purpose(s) and Objective(s) of the Research:

- Dual tasks are characterized by two tasks occurring simultaneously and interference effects are caused when two tasks are carried out at the same time and require the same resources.
- The aim of the research is to use the Three-Dimensional Multiple Object Tracking and a stationary cycle ergometer to introduce a new technique for experimentally investigating dual task effects during moderate physical activity.
- We plan to share the results of this study with you, and the public (e.g., presentations, publications, thesis, etc.). We will take all precautions to protect your confidentiality as described in the Confidentiality section below.

Procedures:

- As a participant you will complete the Demographic and Get Active Questionnaires emailed to you by the researcher before coming to the Motivation for Active Living Laboratory (MALL) located in CKHS 157 to complete the in person cognitive and physical assessments.
- There are 3 cognitive assessments that will take between 20-30 minutes to complete. Prior to completing them you will complete the Demographic Screening Questionnaire, and Mental Fatigue Screening in the MALL. During the cognitive assessment you will be required to put on 3D glasses and a bioharness (to measure heart rate, ECG, etc.). The researcher will give you instructions on how to complete the NeuroTracker Task.
- On the third day, we will also ask you to complete the YMCA Cycle Ergometer Test used to estimate VO2 max. This task will require you to peddle without stopping for a total of
9-12 minutes and will be completed under the supervision of a Canadian Sport and Exercise Physiology certified instructor.

- On the final day, we will ask you to come back to complete the NeuroTracker task while peddling on a cycle ergometer.
- In total, we are asking for approximately 150 minutes of your time spread over 4 days.
- Please feel free to ask any questions regarding the procedures and goals of the study or your role.

Potential Risks:
- The risks associated with participating in this study are minimal. The most prevalent risks could be some mild discomfort causing anxiety or stress during the cognitive and physical assessment evaluation. Additionally, during the physical assessment you may experience increased blood pressure, heart rate and breathing rates resulting in mild fatigue or headaches. You may also experience mild muscle pain, tiredness, and nausea during or after the physical assessments.
- If any anxiety or stress recurs and persists following any of the assessments, we urge you to contact the University of Regina Counseling Services at 306 585-4491. If any physical discomfort recurs and persists following the physical assessment we urge you to contact the University of Regina, Alliance Health medical clinic at (1-306-337-2640).

Potential Benefits:
- There are no direct benefits for participating in this study. However, if you are registered through the University of Regina Psychology Participant Pool you will receive 3 credits for taking part in this study.

Confidentiality:
- Ultimately it is your decision whether or not you wish to participate in this study, only the members of the research team will know you participated.
- Your name will not be mentioned in any of our dissemination methods, so no one will know who participated. Consequently, your choice whether or not to participate in the study will in no way impact your relationship with the University of Regina.
- Once data collection is completed and collated across time points, your information will be coded alphanumerically, so as to further ensure your confidentiality. The file with the identifying information will be securely stored in a location separate from the data file.
- The information you provide will be summarized and combined with all the information gathered from the other participants and no one will be able to link your performances to you.

Storage of Data:
- All identifying information collected at the start of the study (e.g., consent form, contact, and demographic information) will be kept in a locked filing cabinet and will only be available members of the research team.
- Other electronic files will be transferred to a password-protected memory stick and stored in a locked filing cabinet in our laboratory at the University of Regina (Motivation for Active Living Laboratory, CKHS 157) and will be destroyed after a period of 6 years post-publication.
Right to Withdraw:
- Your participation is voluntary, and you can answer only those questions that you are comfortable with. You may withdraw from the research project for any reason, at any time without explanation or penalty of any sort.
- Whether you choose to participate or not will have no effect on your student position or how you will be treated.
- Should you wish to withdraw, simply stop and tell the Principle Investigator you want to stop. At this time, any information that has been collected will be deleted. If you wish to withdraw after the completion of the assessment, please email the principal investigator and apprise her that you wish to withdraw. All collected information will then be deleted.
- Your right to withdraw data from the study will apply until two weeks after the date of your final session. After this date, it is possible that some results have been analyzed, written up, and/or presented and it may not be possible to withdraw your anonymized data.

Follow up:
- An executive summary of the final results of the study will be shared with each participant (via the medium of your choosing).

Questions or Concerns:
- If you have any questions, please contact the researcher(s) using the information at the top of page 1;
- This project has been approved on ethical grounds by the UofR Research Ethics Board. Any questions regarding your rights as a participant may be addressed to the committee at (306-585-4775 or research.ethics@uregina.ca). Out of town participants may call collect.
Consent

Your signature below indicates that you have read and understand the description provided.

I have had an opportunity to ask questions and my questions have been answered. I consent to participate in the research project. A copy of this Consent Form has been given to me for my records.

__________________________  ______________  ______________
Name of Participant        Signature                  Date

__________________________  ______________
Researcher's Signature       Date

A copy of this consent will be left with you, and a copy will be taken by the researcher.

Researchers have my permission to contact me via the following channel to provide me with the results of the study. I understand that this information will be deleted at the end of the study.

Email: ______________________________
        Email address

Mailing address:
        Mailing address

Other: ______________________________
        (please state)
Appendix C

Demographic Questionnaire

Name: ________________________________
Age: ________________________________
Email: ______________________________
Sex: _________________________________
Phone Number: _______________________

How do you wish to be contacted by the researcher circle 1 or both?
• Email
• Phone

Please answer to the best of your ability by circling either yes or no

Are you color vision deficient? Yes No

Have you ever been diagnosed with epilepsy? Yes No

Have you ever been medically diagnosed with ADHD or ADD? Yes No

If you answered “Yes” to any of the above three questions, we thank you for your interest in our study, however, we will not be able to invite you to participate.
Appendix D

Get Active Questionnaire

Physical activity improves your physical and mental health. Even small amounts of physical activity are good, and more is better.

For almost everyone, the benefits of physical activity far outweigh any risks. For some individuals, specific advice from a Qualified Exercise Professional (QEP – has post-secondary education in exercise sciences and an advanced certification in the area – see csep.ca/certifications) or health care provider is advisable. This questionnaire is intended for all ages – to help move you along the path to becoming more physically active.

☐ I am completing this questionnaire for myself.
☐ I am completing this questionnaire for my child/dependent as parent/guardian.

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PREPARE TO BECOME MORE ACTIVE

The following questions will help to ensure that you have a safe physical activity experience. Please answer YES or NO to each question before you become more physically active. If you are unsure about any question, answer YES.

1. Have you experienced ANY of the following (A to F) within the past six months?
   A. A diagnosis/treatment for heart disease or stroke, or pain/discomfort/pressure in your chest during activities of daily living or during physical activity?
   B. A diagnosis/treatment for high blood pressure (BP), or a resting BP of 160/90 mmHg or higher?
   C. Dizziness or lightheadedness during physical activity?
   D. Shortness of breath at rest?
   E. Loss of consciousness/fainting for any reason?
   F. Concussion?

2. Do you currently have pain or swelling in any part of your body (such as from an injury, acute flare-up of arthritis, or back pain) that affects your ability to be physically active?

3. Has a health care provider told you that you should avoid or modify certain types of physical activity?

4. Do you have any other medical or physical condition (such as diabetes, cancer, osteoporosis, asthma, spinal cord injury) that may affect your ability to be physically active?

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NO to all questions: go to Page 2 – ASSESS YOUR CURRENT PHYSICAL ACTIVITY

YES to any question: go to Reference Document – ADVICE ON WHAT TO DO IF YOU HAVE A YES RESPONSE...
Get Active Questionnaire

ASSESS YOUR CURRENT PHYSICAL ACTIVITY

Answer the following questions to assess how active you are now.

1. During a typical week, on how many days do you do moderate- to vigorous-intensity aerobic physical activity (such as brisk walking, cycling or jogging)?
   - Days/Week
   - Minutes/Day

2. On days that you do at least moderate-intensity aerobic physical activity (e.g., brisk walking), for how many minutes do you do this activity?
   - Minutes/Week

For adults, please multiply your average number of days/week by the average number of minutes/day.

Canadian Physical Activity Guidelines recommend that adults accumulate at least 150 minutes of moderate- to vigorous-intensity physical activity per week. For children and youth, at least 60 minutes daily is recommended. Strengthening muscles and bones at least two times per week for adults, and three times per week for children and youth, is also recommended (see csep.ca/guidelines).

GENERAL ADVICE FOR BECOMING MORE ACTIVE

Increase your physical activity gradually so that you have a positive experience. Build physical activities that you enjoy into your day (e.g., take a walk with a friend, ride your bike to school or work) and reduce your sedentary behaviour (e.g., prolonged sitting).

If you want to do vigorous-intensity physical activity (i.e., physical activity at an intensity that makes it hard to carry on a conversation), and you do not meet minimum physical activity recommendations noted above, consult a Qualified Exercise Professional (QEP) beforehand. This can help ensure that your physical activity is safe and suitable for your circumstances.

Physical activity is also an important part of a healthy pregnancy.

Delay becoming more active if you are not feeling well because of a temporary illness.

DECLARATION

To the best of my knowledge, all of the information I have supplied on this questionnaire is correct.

If my health changes, I will complete this questionnaire again.

I answered NO to all questions on Page 1

I answered YES to any question on Page 1

Check the box below that applies to you:

- I have consulted a health care provider or Qualified Exercise Professional (QEP) who has recommended that I become more physically active.
- I am comfortable with becoming more physically active on my own without consulting a health care provider or QEP.

Name (+ Name of Parent/Guardian if applicable) [Please print]
Signature (or Signature of Parent/Guardian if applicable)
Date of Birth
Date
Email (optional)
Telephone (optional)

With planning and support you can enjoy the benefits of becoming more physically active. A QEP can help.

Check this box if you would like to consult a QEP about becoming more physically active.
(This completed questionnaire will help the QEP get to know you and understand your needs.)