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Research article

The execution of the Grooved Pegboard test in a Dual-Task situation: A pilot study

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ABSTRACT

Background: Manual dexterity is an important aspect in everyday life, which is widely studied through the Grooved Pegboard Test (GPT). Since Dual-Tasks (DT) activities are widely investigated and important to simulate everyday life situations, the objectives of the present pilot study were the evaluation of the effect of a cognitive task and a motor task during the performance of the GPT and the feasibility of the GPT in a DT contest. A secondary objective was to evaluate the training effect of the GPT.

Methods: A total of 31 young adults (20 man and 11 woman, age (SD): 27.7 (2.5)) performed the GPT eight times to understand the presence of a training effect before performing the GPT in DT. The additional tasks were a secondary cognitive task and a secondary motor task.

Results: All participants were able to complete the required conditions. The GPT performed in motor DT were significantly slower than those performed singularly ($p < 0.01$). The GPT performed with the cognitive task was slower than the secondary motor task ($p < 0.05$). A training effect was present up to the 4th consecutive trial.

Conclusions: The GPT can be executed with a cognitive or motor task to increase the difficulty of the trial to better evaluate manual dexterity and cognitive capacities.

1. Introduction

Manual dexterity is the ability to coordinate the fingers and manipulate objects promptly in situations such as self-care or leisure activities, typing on a computer keyboard or messaging on a mobile phone, or different work-related activities (Wang et al., 2011). A component widely adopted to evaluate manual dexterity is the time to complete a grooved pegboard (Wang et al., 2011). The National Institutes of Health (NIH) Toolbox for the Assessment of Neurological and Behavioural Function (Gershon et al., 2010) presents two tests for manual dexterity: the 9-Hole Peg Test (9-HPT) and the 25-Hole Grooved Pegboard test (GPT). Manual dexterity has been also evaluated through a different test compared to the GPT and has also been associated with a given cognitive task (Toosizadeh et al., 2016). Furthermore, the pegboard test has been also associated with a cognitive task but evaluated under electrical stimulation (Ljubisavljevic et al., 2019). When an additional task is performed concomitantly to a primary task, this is defined as a Dual-Task (DT) condition (Woollacott and Shumway-Cook, 2002).

The performance of a secondary task influences the results of the primary task and this has been widely investigated during static (Huxhold et al., 2006; Swan et al., 2004) and dynamic postural control situations (Ghai et al., 2017; Smith et al., 2017). The trend of the association between the pegboard test performed with a secondary task seems the same of postural control tasks; the DT condition forces the nervous system to work more efficiently (Ljubisavljevic et al., 2019).

Different forms of secondary tasks (Al-Yahya et al., 2011; Funahashi, 2017) such as manual, reaction time, discrimination and decision making, verbal fluency, mental tracking, and working memory tasks have been previously described. Differences between effects of secondary tasks, such as a mental task and a manual task, on the primary task (during a postural balance evaluation) have been noted (Brustio et al., 2020). Therefore, making interesting to study the influence of different secondary tasks also on manual dexterity. In addition, vision is always required to perform reaction time, discrimination and decision making (such as the Stroop test) and memory secondary tasks (such as the n-back task). Therefore, to understand the influence of a secondary task on

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manual dexterity using a grooved pegboard, it was opted to focalize the attention on working memory (serial three task) and manual tasks (the finger tapping task) which do not necessarily require the use of vision for the secondary task execution.

The main objective of the study was to evaluate the effect of a secondary cognitive and motor task on the GPT. Furthermore, to assess the feasibility of the GPT in association with a cognitive and a secondary motor task. A secondary objective was to evaluate the training curve of the GPT.

2. Materials and methods

2.1. Participants

For this pilot study, the participants were recruited using social networks and flyers from the University of … (hidden to the reviewer) student population. Participants were excluded (i) if they presented injuries or major problems in their upper limbs such as fractures, medical interventions, prostheses, inflammation of the fingers, arms, and shoulders or presented neurological disease; (ii) if they were taking drugs or any medication that could have affected the neuromuscular or cognitive function; and (iii) only right-handers were chosen through the Edinburgh Handedness Inventory (Short Form) test (Veale, 2014).

A final sample of 31 young adults, 20 man and 11 woman (age (SD): 27.7 (2.5); height (SD): 168.7 (8.7); weight (SD): 66.6 (13.1)) were retained for investigation.

Before the study, the participants were informed about the testing procedure. Each participant signed an informed consent to take part in the research. The principles of the Italian data protection (196/2003) were guaranteed. No payment was provided for participation. The Bioetic Ethical Committee of the (hidden to the reviewer) approved the project (number: 11/2020). The study was undertaken following the deontological norms laid down in the Helsinki Declaration (Hong Kong revision, September 1989) and the European Union recommendations for Good Clinical Practice (document 111/3976/88, July 1990).

2.2. Study design

The study consisted of a single session of about 30 min of data collection. All the data were collected in a quiet environment with similar conditions for all the participants. The same investigator proposed the tests using the same standard procedure with all participants.

Before the administration of the tests, the participants were informed about the testing procedures and were required to fill a questionnaire in which information regarding their physical, cognitive and social background were asked. After the initial assessment, each participant performed 10 trials of the GPT with a 1-minute rest between each test. The evaluation consisted of 8 pegboard tests to evaluate the training curve, an adaptation of the neuro-muscular system to repetitive inputs that improve the efficacy of the performance (Gardner, 1967). After the execution of the first phase, the participants performed one GPT associated with a cognitive task (serial three test), and one GPT associated with a motor task (finger tapping test) (Figure 1). The secondary tasks were administered in a random order after the first eight single tasks were performed.

The time for each task was recorded. A detailed description of the tests is presented in the paragraphs below.

2.3. Pegboard test

The 25-Hole GPT (Lafayette Instrument, USA) was adopted to collect the data according to protocols previously adopted (Hamilton et al., 2019; Hamilton et al., 2017; Wang et al., 2011). The test consists of placing keyhole-shaped pegs one by one into 25 holes (in a 5-by5 grid, with different keyhole orientation) from left to right, from top to bottom as quickly as possible. If a peg falls, the participant had to leave it there and continue the test. The participants could only use the right hand and were also required to keep the left hand on the desk. After the description of the test, the participants familiarized the task filling the first top row. This familiarization was performed only before the first GPT. Finally, the operator extracted the pegs and left the participants free to start when they preferred.

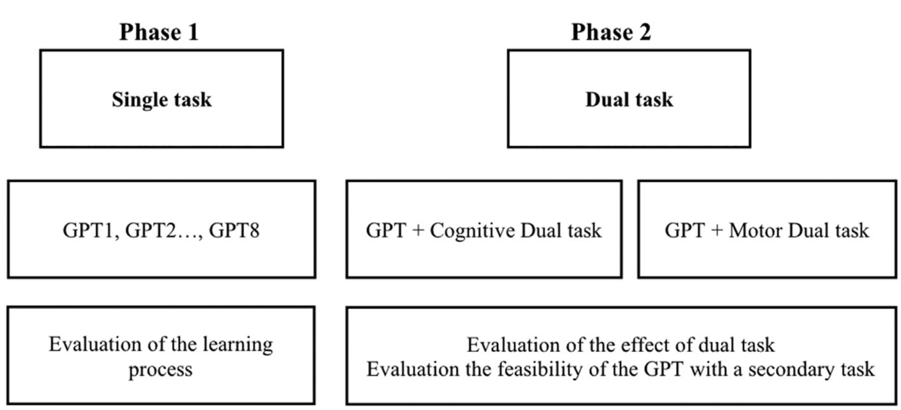
The time to complete the pegboard was recorded with a *Polar M430* device and each recording started when the participant took the first peg and stopped when the last peg was inserted.

2.4. Secondary tasks

A counting backward test (CBT) and the finger tapping test (FTT) were adopted as secondary tasks during the execution of the GPT.

For the secondary cognitive task the "serial three test" was chosen as CBT task. The test consists of counting aloud backwards by three from a randomly selected number between 90 and 100 proposed by the investigator, before the trial was commenced, until the end of the experiment (Pajala et al., 2007). This test is usually adopted for the evaluation of attentional demand (Pellecchia, 2005) and also to evaluate information processing speed (Williams et al., 1996). These were the reasons for this task to be included as secondary task.

The FTT was chosen as secondary motor task. The test evaluates motor speed (Reitan and Wolfson, 1985) and in recent years was also adopted for neuropsychological assessments (Rickards et al., 2018). This test was also proposed in DT evaluation in a modified version, which consists in tapping a surface with the forefinger during the execution of the test (Chagdes et al., 2009). This modified version was adopted in this



GPT: Grooved Pegboard test.

Figure 1. Timeline of the study design.

study. Because the task involves a human movement, it was considered by the authors as a secondary motor task (Al-Yahya et al., 2011; Funahashi, 2017).

2.5. Statistical analysis

For all data, the mean and the standard deviation was calculated. The best (GPTbest) and worst (GPT1) GPTs were retained for investigation for the first 8 tasks. The Shapiro-Wilks test was adopted to assess the normality of the distributions with α at 0.05. The sample size was determined *at-priori* through G*Power software (vers. 3.1.9) adopting the fixed parameters: Effect size (0.22); alpha error probability (0.05); Power for F test family (0.95); number of groups (3); number of measurements (9).

Since data was not-normally distributed, the Friedman test was conducted to evaluate the differences across conditions (i.e., GPT, CBT and TTP) and to evaluate the training effect across the first 8 GPT proposed. To study the training effect between tasks a Dunn's multiple comparisons test was computed.

The statistical analysis was performed through the GraphPad Prism 8.0 for Windows (San Diego, California, USA). The significance level was set at $P < 0.05$.

3. Results

According to the Friedman test, a significant difference was present across the time to complete the GPT between conditions: GPT1, GPTbest, GPT-CBT and GPT-FTT ($p < 0.0001$). Following the execution of the Dunn's test, a significant difference was identified between GPT1 and GPTbest, resulting in 15.5 s as additional time required to complete GPT1 compared to the best performed task ($p < 0.0001$).

When comparing the GPTbest with the GPT-CBT a mean additional time of 13.9 s was required to complete the DT ($p < 0.0001$). Similarly, a significant difference was also present between the GPTbest and the GPT-FTT which resulted in a mean additional time of 7.1 s required to complete the DT ($p < 0.01$).

No difference was found between GPT1 and GPT-CBT (GPT1 1.5 s slower than GPT-CBT) while a difference was noted between GPT1 and GPT-FTT ($p < 0.01$) (GPT1 8.6 s slower than GPT-FTT) (Figure 2).

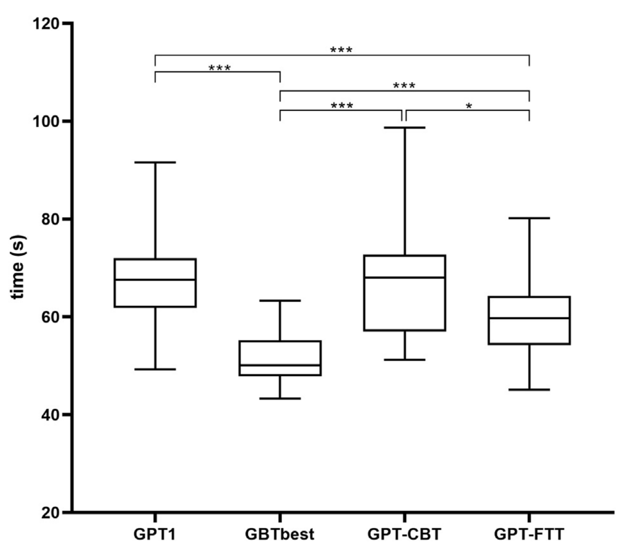


Figure 2. Graphical representation of the Grooved Pegboard Test performed with and without a secondary task. The significativity has been indicated with ***: $p < 0.001$; and *$p < 0.05$. GPT: grooved pegboard test; GPTbest: grooved pegboard test with the best performance after 8 repetitions; GPT-CBT: grooved pegboard test in combination with the counting backward task; GPT-FTT: grooved pegboard test in combination with the finger tapping test.

A difference was also present between the GPT-CBT and the GPT-FFT with a difference of 7.1 s ($p < 0.05$) (GPT-CBT required more time to be completed compared to GPT-FTT).

The statistical test performed between the 8 single-task GPT attempts, revealed an overall difference between the trials ($p < 0.001$). However, no differences were revealed between contiguous tasks (i.e. GPT1 vs GPT2, GPT2 vs GPT3, GPT3 vs GPT4, etc.). A significant difference was found between GPT1 and GPT3 to GPT8, between GPT 2 and GPT5 to GPT 8 and between GPT 3 and GPT5 to GPT 8. No significant differences were present from trial 4 to trial 8. A mean reduction of 10.18 s was observed from GPT1 to GPT4, while from GPT4 onwards the mean difference between the tasks was of 0.45 s (Figure 3).

All results are summarized in the supplementary file named dataset.

4. Discussion

The present manuscript evaluated the effect of a secondary cognitive and a secondary motor task on the GPT and its feasibility. This study was performed to provide new insights regarding the evaluation of manual dexterity associated with executive functioning (Vasylenko et al., 2018).

The first objective of the study was to evaluate the effect of a secondary task on time to conclude the GPT and the results of the study are in line with those previously published by Ljubisavljevic and colleagues (Ljubisavljevic et al., 2019), in which the addition of a secondary task worsened the pegboard test performance. Similar, the deterioration of the main task during a DT condition, is also present during postural balance tasks (Bergamin et al., 2014; Brustio et al., 2020). Our results obtained in DT condition, even if a postural balance task was not involved, are similar to those previously described. Indeed, a correlation exists between upper and lower extremities movements (Fraser et al., 2010), also in a DT setting (Toosizadeh et al., 2016) meaning that the cognitive processes involved are similar.

The important differences between GPT1 during the execution of a secondary task, even if the GPT was proposed multiple times, highlights the challenge for an individual to perform secondary cognitive or motor tasks, notwithstanding a training effect was revealed from the 1st to the 4th GTP task. Consequently, the addition of a cognitive oriented task resulted in worse performance compared to the addition of a motor oriented task, similarly to previous studies (Brustio et al., 2020; Ghai et al., 2017; Woollacott and Shumway-Cook, 2002). Similar findings were also provided regarding DT conditions proposed involving the upper extremities (Toosizadeh et al., 2016).

The differences between cognitive and motor tasks could be explained by the nature of the tasks. Indeed, it seems that a task in which internal factors are involved such as the serial-three test influences much strongly the primary task in comparison to that task which involve external factors such as the finger tapping test (Al-Yahya et al., 2011). To answer the

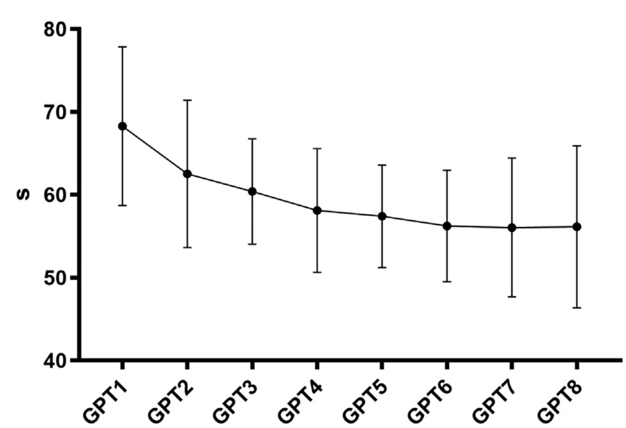


Figure 3. Graphical representation of 8 pegboard trials performed without a secondary task. GPT: grooved pegboard test.

second objective of the study, all the participants were able to perform the required tasks, being these single or DTs. It is important to highlight that a motor task is a condition that could help to understand deeper the nervous system potentiality (Ljubisavljevic et al., 2019); conversely, a cognitive task (serial three counting backward task) is a very challenging condition, especially if proposed to older adults. Finally, in line with previous studies (Marmon et al., 2011; Schmidt et al., 2000), the repetition of the GPT importantly improve the performance during the first three trials. Interestingly, after four GPT trials a significant reduction of the differences between GPT times was noted, reducing the training effect on the results. This point should be further investigated in future studies.

Since the GPT is a relatively easy test to standardize, it should be ideal to propose this test instead of postural balance tasks. Finally, complex finger movements, such as those which the GPT involves, in comparison to simple finger movements as our secondary task proposed, require a larger brain area activation (Sadato et al., 1996), which could provide further information's about cognitive functions.

The strength of the study is the attempt to understand the association between manual dexterity and cognitive functions and the feasibility of the GPT performed with a secondary task.

Future studies should focalize the attention to other populations such as older adults and people with neurodegenerative diseases. Furthermore, it is important to increase the sample size to extend the finding of the present pilot study. It is essential to use different DT settings to understand which secondary task may be proposed.

5. Conclusion

The GPT performed with a DT is a feasible test to evaluate manual dexterity. As expected the DT cognitive condition is a more challenging situation compared to the DT motor condition and the single tasks alone. Also, there seems to be a learning effect regarding the GPT performance which subsided from the 4th task onwards.

Declarations

Author contribution statement

L. Petrigna: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

A. Bianco: Conceived and designed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

A. Palma: Performed the experiments; Wrote the paper.

M. Iacona: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data.

E. Thomas: Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

S. Pajaujiene and A. Paoli: Wrote the paper.

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Competing interest statement

The authors declare no conflict of interest.

Additional information

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