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Unveiling Trail Making Test: visual and manual trajectories indexing multiple executive processes

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The Trail Making Test (TMT) is one of the most popular neuropsychological tests for executive functions (EFs) assessment. It presents several strengths: it is sensitive to executive dysfunction, it is easy to understand, and has a short administration. However, it has important limitations. First, the underlying EFs articulated during the task are not well discriminated, which makes it a test with low specificity. Second, the pen-and-paper version presents one trial per condition which introduces high variability. Third, only the total time is quantified, which does not allow for a detailed analysis. Fourth, it has a fixed spatial configuration per condition. We designed a computerised version of the TMT to overcome its main limitations and evaluated it in a group of neurotypical adults. Eye and hand positions are measured with high resolution over several trials, and spatial configuration is controlled. Our results showed a very similar performance profile compared to the traditional TMT. Moreover, it revealed differences in eye movements between parts A and B. Most importantly, based on hand and eye movements, we found an internal working memory measure that showed an association to a validated working memory task. Additionally, we proposed another internal measure as a potential marker of inhibitory control. Our results showed that EFs can be studied in more detail using traditional tests combined with powerful digital setups. The cTMT showed potential use in older adult populations and patients with EFs disorders.

The Trail Making Test (TMT) is perhaps the most popular neuropsychological task used for standard clinical assessment and research[1–6]. It comprises parts A and B. In part A, the subject uses a pencil to connect a series of 25 encircled numbers in numerical order. In part B, the subject connects 25 encircled numbers and letters in numerical and alphabetical order, alternating between the numbers and letters[2]. It is sensitive to executive function (EF) impairments and has shown consistent results in multiple clinical populations[1,7–9]. Different executive processes are thought to be associated with performance in the TMT, including inhibitory control, working memory, and attention[5,10–12]. In addition to its sensitivity to executive dysfunction, the TMT presents several strengths, as it is simple and intuitive, easy to understand for patients, has a short administration, can be used in different cultures, and the existence of adapted versions allows cross-cultural comparisons[13–15].

However, the standard version of TMT presents severe limitations. First, its multiple underlying EFs are not well discriminated, which makes it a test with low specificity. Solving the TMT involves the articulation of multiple processes (e.g. motor preparation and execution, visual search, visuomotor planning and coordination, working memory, inhibition, among others). The behavioural scores do not disentangle these processes, and the final performance constitutes a rough summary and undiscriminated assessment[12]. This is known as *the impurity*

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