

EFFICACY OF THE COLOR TRAILS TEST FOR ASSESSMENT OF COGNITIVE IMPAIRMENTS AND MEASUREMENT OF THERAPEUTIC OUTCOMES: A SYSTEMATIC REVIEW

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ABSTRACT

Background: Accurate assessment of cognition is important in planning interventions for best outcomes for patients with neurologic deficits. The Color Trails Test (CTT) examines attention, sequencing, and mental flexibility, however, few studies examine the efficacy of the CTT in therapeutic rehabilitation. The objective of this systematic review was to examine the efficacy of the CTT for determining appropriate interventions and assessing functional outcomes. **Methods**: PubMed, CINAHL, and EMBASE databases were searched in April 2018 with no date restrictions. The search yielded 352 articles to be screened by title, duplication, abstract, and full text application of inclusion/exclusion criteria. The final screen left 7 articles which were scored using the 2011 Oxford Centre of Evidence-Based Medicine (CEBM) criteria to assess level of evidence based on design. Additionally, three of the articles, which incorporated physical therapy interventions, were scored using the PEDro scale to assess quality. **Results:** Of the seven articles selected for review, four used the CTT as a method of assessment, while three used it as an outcome measure. Findings suggest the possible usefulness of the CTT both as an assessment tool, and a measure of progress in motor control related to attention and sequencing deficits. **Conclusion:** The CTT may be a useful tool for clinicians to utilize as a method of assessment prior to establishing treatment plans and in measuring outcomes related to improvement in motor sequencing and function in patients with neurologic deficits related to stroke and other diagnoses.
Keywords: Color Trails Test, attention, sequencing, rehabilitation, motor control

INTRODUCTION

Cognition, specifically attention span and sequencing, are important components in recovery from neurologic deficits. Decreases in the duration of care, coupled with limitations in the number of allowed physical therapy treatments, create a vital need for physical therapists to accurately assess patients to develop a comprehensive plan of care for optimal outcomes. In a study by Donoghue et al. [1] a correlation was shown between performance of a functional activity as measured by the Timed Up and Go (TUG) and executive function including attention and sequencing as measured by the Color Trails Test (CTT). Lower scores on cognitive tests correlated with slower performance of the TUG. This indicates the importance of including cognitive tests such as the CTT into initial assessments for optimal outcomes.

Fast, accurate assessment of cognition is important in planning and implementing a comprehensive plan of care for interventional strategies to achieve best outcomes. The Color Trails Test (CTT), designed in 1989, was a response to the World Health Organization's request for a test similar to the Trail Making Test in psychometric properties but without cultural and ethnic limitations for clients who speak and read a language other than English. [2] The CTT allows for multicultural application while minimizing linguistic and phonetic factors. [2, 3] Historically, the CTT has been mainly used by neuropsychologists to examine attention, sequencing, and mental flexibility. [4, 5] The CTT consists of two timed subtests: the CTT1 measures attention and the CTT2 measures sequencing. [6, 7, 8]

CTT1 consists of 25 numbered circles with yellow and pink backgrounds for even and odd numbers, respectively. [3] The use of pink and yellow are used to decrease negative effects of testing for individuals with colorblindness. The client is instructed to sequentially order the numbered circles by drawing a line from the lowest number to the highest. In the CTT1, the colors of the circles are not considered in the successful completion of the test.

The CTT2 has 25 yellow and 25 pink numbered circles. The participant is again instructed to draw a line in sequential order with the added task of alternating colors. This adds a divided attentional component as the participant must disregard the numbers in the wrong colored circles. [2, 3, 6] Overall scoring assesses time to completion, errors, near misses, and prompts.[9]

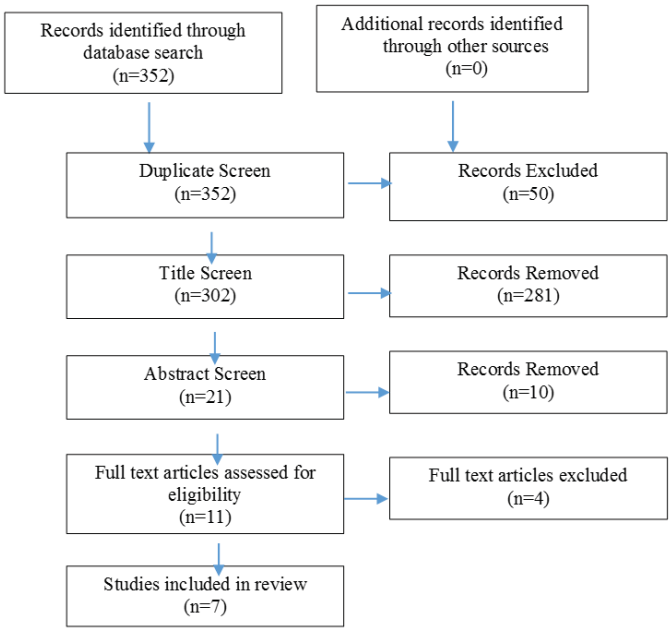
The scores on the CTT are standardized based on normative data accounting for age and education. [3, 10] For normalization of data, 1,528 healthy volunteers were tested. The volunteers did not have a history of neurological, social, medical, or psychological issues that could potentially impact performance on the CTT. [9] The volunteers consisted of adults ages 18-89 with Caucasians, Hispanics and African Americans comprising 69%, 19%, and 12%, respectively. Researchers then separated the results by age and educational background to determine normative values. [9]

Relatively few studies examine the efficacy of the CTT in treatment planning and outcomes from a therapeutic rehabilitation standpoint. The purpose of this systematic review was to examine the efficacy of the CTT as an instrument to assess attention and sequencing for determining appropriate therapeutic interventions, and as a measure of functional outcomes.

METHODS

In April 2018 the PubMed, CINAHL, and EMBASE databases were searched without date restrictions and using identical search terms including “rehabilitation”, “Color Trails Test”, “physical therapy”, “sequencing”, “fine motor”, and “functional activity”, in various combinations. Following the electronic search, 105 articles were screened by title, duplication, abstract, and full text application of inclusion/exclusion criteria (see Figure 1). Inclusion criteria were subjects with neurologic diagnoses or diabetes. Exclusion criteria were (1) children, (2) subjects with alcoholism, (3) subjects with mental illness, or (4) use of the Trail Making Test. The final screening process left 7 articles which were assessed for study quality and validity using the 2011 Oxford Centre of Evidence-Based Medicine (CEBM) and the PEDro scale. The CEBM assesses study quality based on the design, and is a 5-point scale with lower numbers indicating a higher level of evidence. Additionally, three of the articles were appropriate for scoring using the PEDro scale for physical therapy research. PEDro is a 10-point scale used to measure internal validity of physical therapy interventional studies. The average PEDro score of the three articles was 7.3/10.

Figure 1. Diagram of Search Strategy



RESULTS

Of the seven articles selected for review, three articles incorporated the CTT as a diagnostic tool for assessing cognitive impairment. Four studies used the CTT in evaluating the effects of specific interventions and measuring the outcomes for improved cognitive function.

CTT as an Assessment Tool

Hartman-Maeir et al., (2008) [3] assessed the validity of incorporating the CTT as a clinical test to determine readiness for return to driving in 30 participants following acquired brain injury (ABI). In this study, ABI was defined as stroke, traumatic injury, and anoxic brain injury with 17, 9, and 4 subjects respectively. Each participant completed the CTT 1, CTT2, the Useful Field of View (UFOV), and an on-road evaluation. The UFOV test was used to assess visual spatial attention, and revealed significant moderate correlation with the CTT1 and the CTT2 in the correlation analysis within this study.

The sample was divided into two groups based on performance in the on-road evaluation. Half the group passed the test and were deemed competent to drive based on the on-road assessment. Analysis revealed that 87% of the participants who failed the on-road test took more than 60 seconds to complete the CCT1. Conversely, 70% of those who passed the on-road evaluation completed the CTT1 in less than 60 seconds. Between-group comparison indicated that the pass group scored significantly better on the CTT1 compared to the fail group ($p = 0.023$), and the performance of CTT2 was nearing significance ($p = 0.089$). The results of this study may support the use of the CTT as one possible component of an examination prior to returning to driving, as a screening tool to quickly assess risks associated with unsafe driving, and useful in developing rehabilitation interventions aimed at attention and sequencing to improve motor control.

In a study by Chan et al., (2003) [7], the CTT was used to examine attentional deficits in patients with prolonged post-concussive symptoms. Based on a previous study by Chan, the author described attention as having four separate components including sustained attention, divided attention, selective attention and attentional control processing. [11] The current study utilized tests and measures to further define each of the three attentional components within 92 participants. Each participant completed two tests for sustained attention, two tests for selective attention, and four tests for divided attention/processing. The CTT was one of the measures used to measure selective attention.

Analysis identified and described three separate levels of attention disorders defined as mild attention deficits related to intensity, deficits in selective and divided attention, and general attention deficit. Findings specific to the CTT showed participants with mild deficits performed significantly better on the CTT when compared to those with selective and divided deficits ($p < 0.005$) and those with a general attention deficit ($p < 0.005$). Furthermore, participants with deficits in selective and divided attention outperformed those with general attention deficits ($p < 0.005$).

In addition to assisting in determining readiness for driving and as an assessment of attention, the CTT may be used to indicate subclinical disease. In a 2008 study, Wright et al. [12] assessed 656 participants from a random population-based cohort study for cognitive abilities using the CTT. The participants were tested using magnetic resonance imaging to assess for white matter hyperintensities (WMH) and subclinical cerebral infarcts to identify brain disease that was not manifested at a clinical level. Of these participants, 104 were confirmed to have subclinical infarcts (SI) and 164 were discovered to have WMH which were categorized into quartiles in order of increasing severity.

The CTT1 was incorporated as a 4-minute test to measure sequencing, while the CTT2 was used as a 5-minute test to measure cognitive flexibility. Results indicated decreased performance in cognitive flexibility as the severity of WMH increased. This comparison became significant with the 3rd quartile compared to the first quartile after adjusting for age, and with the 4th quartile adjusted for age and education. When assessing performance on the CTT in participants with SI, those with deficits in the deep grey matter performed significantly worse in sequencing ($p = 0.05$), while participants with deficits in the frontal cortex performed significantly worse in cognitive flexibility ($p = 0.02$). This suggests that the location of infarct may be a consideration when planning therapeutic activities designed to improve sequencing and cognitive flexibility.

CTT to Measure Outcome

Whereas the above articles used the CTT as an assessment tool, other studies suggest its usefulness as a tool to measure outcomes following rehabilitation interventions. In a study designed to determine the effect of self-regulation and guided reflection on attention and information processing, Liu, et al (2014) [6] conducted a randomized controlled trial of 44 participants with acute one-side middle cerebral artery (MCA) stroke. The CTT1 was used as a measure of attention and the

ability to process information. The CTT2 was administered to test ability to perform sequencing as a measure of executive processing. Assessment was performed one day before and after interventions. The control group performed traditional occupational and physical therapy for one hour each day for five days. The experimental group performed the same interventions with the addition of self-regulation and guided reflection provided by a therapist. The control group showed no difference in CTT1 or CTT2 performance, and between group comparisons showed no differences on either subset of the CCT. However, the experimental group showed significant improvement on CCT1 ($p = 0.002$), indicating improved attention and information processing. Overall, the results indicated self-regulation and guided reflection are beneficial in addressing both attention and information processing deficits.

In addition to measuring changes in attention and processing, the CCT has also been used to determine the effect of therapeutic interventions on functional tasks. Liu et al., (2004) [10] conducted a study to determine the efficacy of mental imagery for improved performance of functional tasks after a stroke. A total of 46 participants were randomly assigned to either an experimental group who performed mental imagery or the control group who performed conventional functional training. All participants also received physical therapy for walking and general strengthening in one hour sessions, five days a week for three weeks. Results of the study revealed that the mental imagery group reached a superior level of performance with daily functional tasks compared to the control group. Univariate analysis indicated that the mental imagery group showed significant improvement ($p = 0.03$) in subscale scores for CTT2 compared to the control group, indicating the value of including mental imagery as an adjunct treatment for improved attention and sequencing for improved relearning and performance of daily functional tasks.

Because the CTT 1 and CTT2 measure cognitive and motor aspects of attention and sequencing, it may be used to measure the efficacy of a therapeutic intervention in all areas of rehabilitation. In a 2015 study, Marshall et al., [8] utilized three participants, ages 49, 51, and 74, who had been diagnosed with stroke, to assess the potential effects of unilateral forced nostril breathing (UFNB) as an adjunct treatment to standard speech therapy interventions for aphasia. Participants performed UFNB for 40 minutes daily for 18 – 25 sessions, in addition to traditional aphasia intervention. Repeated assessments using the CTT were used to measure attention.

The CTT was given as a pre-assessment and to establish baseline. The intervention phase included the participant performing UFNB using the nostril contralateral to the side of the brain lesion. Measurements of the CTT1 and CTT2 were taken at each session. The overall result of the study indicated no significant change in CTT scoring from pre and post intervention, indicating that UFNB is not an effective treatment to improve attention and sequencing, allowing the therapist to quickly modify interventional strategies for improved outcomes.

In addition to its use in measuring cognitive functioning in people with neurologic diagnoses, the CTT may be useful in developing appropriate interventions for people with other diagnoses. Anderson-Hanley (2012) [5] assessed the potential influence of exercise on cognitive function of older adults with diabetes by examining outcomes from 20 participants enrolled in a large randomized control trial. The subjects were randomly allocated to an exercise group using a traditional stationary bike or a group using a cybercycle which included a virtual reality component for visual input. For the purposes of the prospective analysis, the 20 participants were further divided into two groups: 10 participants with diabetes and 10 without diabetes to be used as age-matched controls. All participants performed 45 minutes of stationary cycling exercises, two to five days a week for a period of three months.

The CTT2 was given 3 times during the study: first as a pre-test to limit practice effects, then one month later just before starting the exercise, and finally at the end of the three months of exercise as a post-test. Analysis was limited to the second and third assessments. The experimental group with diabetes showed significant improvement in the CTT2 score ($p = 0.02$), while the age-matched control group without diabetes indicated no change. Between group comparison showed significant improvement in performance on the CCT2 ($p = 0.007$) in the experimental group as compared to the control, indicating improved cognitive function in older adults with diabetes. Results suggest that exercise may assist in improving cognitive sequencing ability in people with diabetes as measure by the CTT.

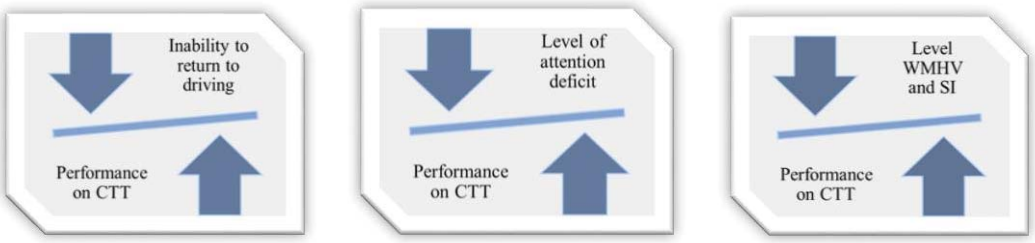


Figure 2: Assessments of cognitive deficits using the CTT indicating worsening performance on the CTT with increases in cognitive deficits

DISCUSSION

Quickly and effectively determining a client's attentional focus and sequencing ability may allow therapists to develop improved strategies for optimal rehabilitative interventions. This review of the literature suggests the possibility of incorporating the CTT as a means of assessment for cognitive deficits and as a means of measuring outcomes following intervention. Retesting utilizing the CTT1and CTT2 could potentially guide the therapist on when to transition clients to the next phase of motor learning for improved outcomes.

Studies that used the CTT for assessment found it useful in assessing readiness for return to driving, identifying levels and types of attention deficit, and determining deficits related to subclinical brain disease. [2, 7, 12] As performance on the CTT decreased, increased levels of cognitive deficits were found (see Figure 2). Utilizing the information gleaned from use of the CTT may be helpful in a rehabilitation setting to guide clinicians in establishing treatment plans that facilitate the best intervention for the client, given the severity of cognitive deficit leading to better treatment choices.

In addition to utilization of the CTT as a method of assessment, findings suggest that it may be useful as an outcome measure to demonstrate level of improvement in sequencing and function following rehabilitation. Three of the studies utilized the CTT as part of pre-and post-test measures that indicated a significant improvement following the specified intervention. [6, 5, 10] Extending this concept into the clinical environment, the use of the CTT for initial assessment of attentional and sequencing deficits in clients with neurologic diagnoses may not only yield useful information regarding the level of deficit, but may also provide a valuable outcome measure at discharge.

CONCLUSIONS

Improved performance on the CTT may indicate improvement in attention and/or sequencing as function improves. The CTT is a simple and quick tool that can be incorporated into clinical rehabilitation settings as a focused measure of attention and sequencing ability or inability which may add to successful patient outcomes. A limitation of this review was the relatively small number of studies that specifically use the CTT as an assessment or outcome measure in clients with neurologic deficits resulting in physical and cognitive dysfunctions common in people with neurologic conditions.

DISCLOSURES

Financial Disclosures: None of the authors received financial assistance of any kind for this project.
Conflicts of Interest: None of the authors have a conflict of interest to report.
Conflicts of Interest: No conflicts of interest were declared by any author.
No use of animals was incorporated within this study.
IRB approval was not mandated since it is a review of published manuscripts.

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