Journal of Safety Research 48 (2014) 19–25

Contents lists available at ScienceDirect

Journal of Safety Research

journal homepage: www.elsevier.com/locate/jsr

Using cognitive status to predict crash risk: Blazing new trails?

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ARTICLE INFO

Article history:
Received 3 July 2013
Received in revised form 18 October 2013
Accepted 23 October 2013
Available online 6 November 2013

Keywords:
Crash risk prediction
Driver
Aging
Cognitive impairment
Trail making Test

ABSTRACT

Introduction: A computer-based version of an established neuropsychological paper-and-pencil assessment tool, the Trail-Making Test, was applied with approximately 700 drivers aged 70 years and older in offices of the Maryland Motor Vehicle Administration. *Method:* This was a volunteer sample that received a small compensation for study participation, with an assurance that their license status would not be affected by the results. Analyses revealed that the study sample was representative of Maryland older drivers with respect to age and indices of prior driving safety. The relationship between drivers' scores on the Trail-Making Test and prospective crash experience was analyzed using a new outcome measure that explicitly takes into account error responses as well as correct responses, the error-compensated completion time. *Results:* For the only reliable predictor of crash risk, Trail-Making Test Part B, this measure demonstrated a modest gain in specificity and was a more significant predictor of future safety risk than the simple time-to-completion measure. *Impact on industry:* Improved specificity and the potential for autonomous test administration are particular advantages of this measure for use with large populations, in settings such as health care or driver licensing.

1. Introduction

Motor vehicle crash statistics show that, relative to their miles driven, older drivers are at greater risk of fatal crash involvement than any group except newly licensed, teenage drivers (Insurance Institute for Highway Safety [IIHS], 2008). These data have spurred research into which domains of functional ability that decline reliably with advanced age can significantly predict crash risk for this group and how best to measure such deficits. This body of evidence has in turn supported recommendations such as those resulting from the 2008 North American License Policies Workshop, which stated as its highest priority model licensing system element that "driver assessment should not be age-determined, but triggered by decreasing functional ability, as measured objectively through screening" (Molnar & Eby, 2008). Among the objective measures of functional (cognitive) ability that have emerged as the strongest predictors of crash risk for older drivers is the Trail-Making Test (Ball et al., 2006; Staplin, Gish, & Wagner, 2003; Stutts, Stewart, & Martell, 1998).

The use of the Trail-Making Test to assess cognitive dysfunction dates to the 1950s (Reitan, 1958). This venerable instrument is a timed test of an individual's ability to "connect the dots," initially presented on a sheet of paper and more recently on a computer screen. In Part A, the dots are labeled with numbers only (1 through 25) and in Part B, half are labeled with numbers (1 through 13) and half are labeled with letters (A through L). The dots are arranged randomly across the page/screen. The task in Part A is to connect the dots in ascending sequence (1, 2, 3, etc.), and in Part B, to connect them in *alternating* ascending sequence (1, A, 2, B, etc.). The lines connecting each number/letter are the "trails" referenced in the name of the test.

Studies examining how performance on the Trail-Making Test relates to traffic safety have, for the most part, focused on Part B when generalizing findings to a broad cross section of the (older) population. There is a strong "ceiling effect" with associated restriction of range for performance on Part A, which makes it difficult to detect reliable effects (although, anecdotally, clinicians working with older patients with dementia find that results on Part A are more reliable, as few who are so afflicted can complete Part B). Although both parts of this test involve directed visual search, Part A has been characterized primarily as a measure of processing speed (Tombaugh, 2004), while differences in performance on Part B are often attributed to attention switching difficulties; although not all research supports this interpretation (cf. Salthouse et al., 2000). In crash prediction research, Part B has been associated with the construct, "directed visual search with divided attention" (Staplin, Lococo, Gish, & Decina, 2003).

This characterization of the Trail-Making Test underscores its candidacy to serve as one component in an emerging standard for "cognitive fitness to drive." In the driving situation where older adults are most at risk—intersections (cf. Stutts, Martell, & Staplin, 2009)—the operational significance of this functional ability is

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0022-4375/$ – see front matter
http://dx.doi.org/10.1016/j.jsr.2013.10.004

undeniable. A driving task analysis for an intersection approach reveals numerous attentional targets distributed across the driver's field of view including geometric features plus traffic control information conveyed by signs, signals, and pavement markings, to which a motorist must dynamically allocate capacity in relation to a host of contextual variables such as road and visibility conditions; the presence of cyclists or pedestrians, traffic speed and density, and the anticipated movements of other vehicles (cf. Staplin, Gish, Decina, Lococo, & McKnight, 1999), all under considerable time pressure.

This element of time pressure is captured in the instruction protocol for the Trail-Making Test via directions to "connect all of the numbers (and letters), in order, as quickly as possible."

However, there is no penalty when a test taker makes a mistake by overlooking a target and selects a number (or letter) out of sequence, except to extend the time for test completion. In this instance, he or she is so notified of the mistake by the test administrator (or computer) and prompted to "not start over, just continue from the last correct response" (which is facilitated by the visible "trails" showing the locations of previous correct responses). When actually driving, of course, failure to successfully search for and recognize even a single, situationally critical element can have serious safety consequences. Someone challenged by this dynamic driving task cannot—as when viewing an array of static test stimuli—unilaterally extend the interval for timely and accurate decision making, as required for appropriate vehicle control actions.

This suggests a potential for refinement of the conventional outcome measure in the Trail-Making Test (i.e., total completion time). In the practice of clinical neuropsychology, error rate is not recorded as it is assumed that if errors are made this will be reflected in a longer completion time (Tombaugh, 2004). However, can we equate the functional status of an individual who completes the test in a given interval but makes several mistakes with another who evidences the same completion time with error-free performance?

This question is addressed through an analysis of Trail-Making Test performance, using computer-based test administration, which examines the prospective crash experience of a representative sample of approximately 700 drivers aged 70 years and older. The results could be beneficial not only for applications specific to driver licensing but also for any clinical application of this measure of cognitive status.

2. Methods

The study sample was comprised of 692 drivers recruited from visitors to one of four Maryland Motor Vehicle Administration (MVA) field offices to conduct business (license renewal, title transfer, etc.) between September 2008 and June 2009. All persons aged 70 years or older with a valid Maryland driver's license were eligible to participate. The study sites included a large city (Baltimore), a small city (Annapolis), a suburban location (Loch Raven/Parkville), and a rural location (Easton).

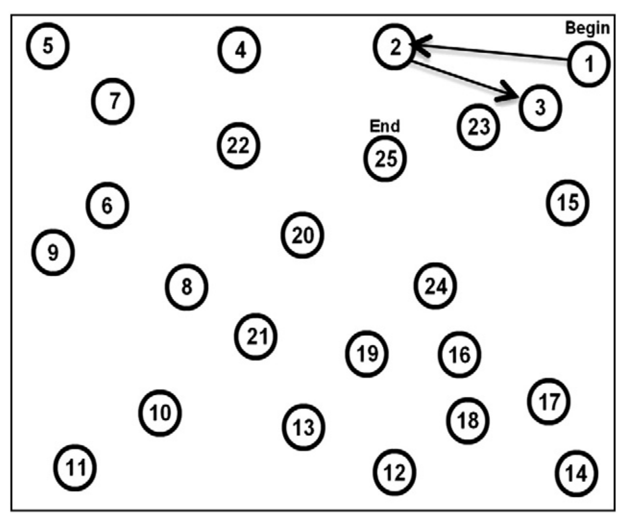
Prospective study participants were contacted in one of two ways: a counter staff member at the MVA told drivers whose date of birth identified them as potential participants about the study and provided a research flyer or the MVA mailed a letter to older drivers in the geographical catchment area of each field office whose license renewal date was approaching in the next month, advising them of this research opportunity. Both methods directed interested persons to project research assistants (RAs) on site at each MVA office for more information.

Recruitment procedures, including informed consent procedures, were carried out according to protocols approved by the Institutional Review Board at Chesapeake Research Review. Those seeking more information were informed that this was a federally sponsored research study in which (a) all data are reported at the group level and no individuals would be identified and that (b) study participation "will not affect your driver's license in any way." They received a description of the research project, including the IRB-approved consent form, and learned that compensation (in the form of a $25 gift card for use at local convenience stores) was offered for their participation. Those who assented to participate in the research were guided to a nearby private office, where the RA completed computer-based functional assessments, including the Trail-Making Test, using a Windows® 2000 PC with a resistive-based touch screen display (Synaps Model S15TSM 15-in LCD TFT, 1024 × 768).

Part A of the Trail-Making Test was always administered before Part B to comply with the clinical protocol for this assessment: to avoid confounding, test takers became acquainted with the directed visual search element of the test in Part A before they were confronted with the divided attention element of the test in Part B. The instructions for each procedure follow, with a graphic showing the actual test stimuli for both parts of the test. The included arrows illustrate how each element is touched in turn.

Part A

> The next page contains the numbers 1 through 25 scattered randomly across the screen. Touch each number in turn, as fast as you can. Your score is the time it takes to find and touch all 25 numbers, in order, without skipping any.
>
> All of the numbers you touch correctly will be connected with lines on the screen. These will help you find the next number, if you make a mistake. If you make a mistake, continue from your last correct response—do NOT start over.
>
> The number "1" is in the upper right hand corner. Touch it immediately when the next page appears, then continue with every other number, in order.



Part B

> The next page contains both numbers and letters scattered across the screen. Touch the number "1" first, then the letter "A," then the number "2," then the letter "B," and so on. Your score is the time it takes to find and touch all of the numbers and letters in this alternating order.
>
> All of the numbers and letters you touch correctly will be connected with lines on the screen. These will help you find what to touch next, if you make a mistake. If you make a mistake, continue from your last correct response—do NOT start over.
>
> The number "1" is in the upper right corner. Touch it immediately