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Examining the effects of the TASER on cognitive functioning: findings from a pilot study with police recruits

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Abstract

Objectives Despite its widespread adoption by more than two-thirds of police departments in the US, there has not been a single study examining the effects of the TASER on cognitive functioning. This inquiry is important for two reasons. First, research has consistently documented cognitive deficits following exposure to electricity (the TASER is an electrical device). Second, questions have emerged regarding whether TASER exposure impairs suspects' ability to understand and waive their *Miranda* rights.

Methods To explore this issue, the authors carried out a pilot study with 21 police recruits who received a TASER exposure as part of their training at the San Bernardino County (CA) Training Center. Each recruit was given a battery of cognitive tests 3–4 h before TASER exposure, within 5 min after exposure, and again 24 h after exposure.

Results Recruits experienced statistically significant reductions in several measures of cognitive functioning following TASER exposure. However, all recruits had returned to their baseline levels of functioning within 24 h. Learning effects were documented in several of the cognitive tests.

Conclusions The questions driving this study involve serious issues including constitutionally protected rights of the accused, use of force by police, and previously unexamined effects of the TASER on the human body. The pilot study represents a

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critical first step in exploring the effects of the TASER on cognitive functioning. Moreover, the results provided the authors with important information that will guide their larger study, a randomized controlled trial where healthy human volunteers will be randomly assigned to four groups, two of which receive a TASER exposure.

Keywords TASER · CED · Electrical injury · *Miranda* waiver · Police use of force

Introduction

Conducted electrical devices (CEDs) such as the TASER have emerged as a preferred less-lethal weapon among police agencies throughout the United States and abroad (e.g., compared to batons, pepper spray, etc.). The TASER fires two small probes which stay connected to the device and generate a high-voltage (50,000 V), low amperage (2.1 mA) current of electricity over a period of 5 s (at a minimum). TASER International, a leading developer of CED technology, states that its device has been adopted by nearly 17,000 police departments in 107 countries, including departments in 29 of the 33 largest cities in the U.S. (http://www.taser.com). TASER International also estimates that by October 2013 there have been more than 1.99 million uses of its device in the field.[1] Given the rapid diffusion of CEDs in policing, empirical research has failed to keep pace regarding its potential effects on human subjects. This lag has brought to light a number of contentious questions surrounding police use of CEDs, including questions of appropriate use (i.e., policy questions about when and how to use the device, as well as against whom), effectiveness (i.e., impact on suspect resistance and prevalence of suspect and officer injuries), and physiological impact (i.e., the risk of injury or death) (Alpert and Dunham 2010; White et al. 2013).

Over the past few years, however, both social scientists and medical researchers have begun to close the gap between research and practice involving CEDs, particularly with regard to physiological risks (NIJ 2011; Pasquier et al. 2011; Vilke et al. 2011). Though a substantial body of research has examined physiological risks, there has not been a single study testing the effects of CEDs on cognitive functioning, such as memory, concentration, and speed of learning. This area of inquiry is important for two reasons. First, there is a considerable body of research examining the neuropsychological effects of accidental exposure to electricity, and this research has consistently demonstrated deficits in functioning following the electrical exposure (Duff and McCaffrey 2001; Pliskin et al. 1994). It is not known whether the documented cognitive deficits from electrical injury (EI) also extend to the TASER, which is an electrical device. If the TASER does cause cognitive impairment, this finding would have important implications for police policy and practice.

Second, defense counsel in several recent criminal cases have sought to suppress arrestees' statements made to police after their clients were exposed to a CED, arguing that use of the device causes a degree of mental impairment that violates arrestees'

[1] CEDs are sometimes called CEWs, conducted electrical weapons, or ECDs, electronic control devices. TASER International also estimates that there have been approximately 1.35 million voluntary or training exposures with their device(s). TASER International has also sold more than 260,000 devices to private consumers. Though the TASER is only one brand of CED, it is the most commonly used device in the United States. Moreover, the recruits whose experiences are described in this paper were exposed to a TASER X26 model. As a result, the terms "TASER" and "CED" are used interchangeably throughout this paper.

constitutional protections involving *Miranda* rights and the requirements for valid waiver of those rights (e.g., *U.S. v. Mack*, Middle District of Louisiana, No. 07-238, JJB). The absence of research examining the link between CEDs and cognitive impairment gives trial courts little guidance on how to rule on these arguments, thereby leaving judges to make idiosyncratic decisions about the constitutionality of *Miranda* waivers and the admissibility of evidence in such cases.

The authors have been funded by the National Institute of Justice to examine the effects of the TASER on cognitive functioning. The centerpiece of the research involves a randomized controlled trial (RCT) where healthy human volunteers will be recruited, screened, and randomly assigned to one of four treatment conditions, two of which will receive a TASER exposure (using a within subjects 2 × 2 factorial design). Given the complexity of this line of inquiry and the difficulties of successfully carrying out an RCT in the field, the authors first devised a pilot study to explore issues and questions surrounding the cognitive effects of a TASER exposure. This paper presents the findings from the pilot study. The study was carried out in April–May 2012 with police recruits at the San Bernardino County, CA Sheriff's Training Center, who were scheduled to receive a TASER exposure as part of their training (n=21). Each of the recruits was asked to complete a series of cognitive tests at three points in time: 3–4 h prior to TASER exposure (baseline); immediately after (within 5 min) TASER exposure; and again 24 h after exposure.

The authors sought to accomplish three objectives with this pilot study. First, the pilot study offered an opportunity for a "test run" in terms of methodology, logistics, and testing protocols (e.g., sequence and timing of cognitive tests). Second, despite the small sample size, the pilot represented a first effort at empirically measuring whether the TASER produces significant changes in cognitive functioning. Third, the pilot study allowed the authors to proceed cautiously and to consider a range of important methodological and logistical issues that represent challenges for empirical research in this area. The paper begins with a review of the relevant literature and methodology, followed by presentation of the findings from the pilot study. The paper concludes with a discussion of the implications of the pilot study findings for both the planned RCT and the larger literature on the TASER and its effects on the human body.

Literature review

Police use of CEDs, unresolved questions, and controversies

Police leaders have continually sought to expand force options for their line officers to increase control over combative suspects and to reduce the prevalence and seriousness of injuries (Alpert et al. 2011). Over the past decade, the TASER has become one of the preferred less-lethal weapons in many police departments across the US. For example, nearly 7,300 police departments have issued the TASER to all of their line personnel, and 720,000 devices have been issued to police officers worldwide (http://www.taser.com). However, a number of concerns have emerged involving police use of the TASER.[2] One area that has generated some controversy is centered on when, against whom, and under what conditions the device should be used (e.g., use against passive

[2] See White and Ready (2010) for a more detailed review of these areas of concern.

resisters and vulnerable persons). For example, Alpert and Dunham (2010) noted that departments vary substantially in their placement of CEDs on the force continuum, as well as in how they permit their officers to use the device. A second area of contention involves the effectiveness of the device, measured most commonly as a reduced prevalence of injuries (though see White and Ready's 2010, 2007 research on reduced suspect resistance). Several studies have demonstrated reductions in officer and suspect injuries after TASER adoption (Alpert et al. 2011; Police Executive Research Forum 2009; Smith et al. 2007, 2009).

The third area of contention involves the physiological effects of the TASER, most notably whether it poses an increased risk of death. Recent estimates indicate that more than 500 people have died after being exposed to a TASER (http://www.amnestyusa.org). A large body of research has explored the effects of CEDs on human beings both in laboratory settings and in the field, focusing primarily on cardiac rhythm disturbances, breathing, metabolic effects, and stress (Bozeman et al. 2009; Ho et al. 2006; NIJ 2011; Pasquier et al. 2011; Vilke et al. 2011). This research has consistently concluded that the TASER poses low risk for healthy human adults, and that deaths following exposure are caused by other factors including substance abuse, pre-existing medical conditions, and excited delirium (NIJ 2011).

Electrical injuries and neuropsychological effects

Given that the TASER is an electrical device, the literature on electrical injuries provides an important backdrop for considering the potential neuropsychological effects on suspects. A sizeable body of research has examined the neuropsychological effects of accidental exposure to electrical power (e.g., workers on power lines).[3] These studies have consistently documented deficits in neuropsychological functioning, particularly in the domains of memory, attention, and concentration (Barrash et al. 1996; Crews et al. 1997; Daniel et al. 1985; Duff and McCaffrey 2001; Fish 2000; Hooshmand et al. 1989; Hopewell 1983; Miller 1993; Varney et al. 1998). Moreover, a number of studies have suggested the potential for onset of psychiatric disorders such as depression and schizophrenia-like illnesses (Zia Ul Haq et al. 2008), as well as post-traumatic stress disorder (Premalatha 1994). In the most extensive research to date, Pliskin et al. (2006) conducted a series of studies comparing 63 electrical injury (EI) victims to 22 non-EI electrician control subjects. The findings indicated that EI victims reported a much higher rate of physical, cognitive, and emotional problems, with nearly 50 % reporting some type of cognitive difficulty (most commonly concentration problems, slower thinking, and impaired memory). EI victims also performed more poorly on a battery of cognitive tests. Pliskin et al. (2006) noted that some of the problems persisted for years after the event, and that the nature of cognitive difficulties was not related to the severity of EI injury (e.g., voltage exposure).[4] In their review of the existing literature on EI injuries, Duff and McCaffrey (2001) categorized study results across eight domains

[3] Research in this area considers electrical injuries and injuries from lightning strikes together, but we focus our attention on electrical injury (EI) victims only. Though the symptoms and effects appear similar, lightning strike injuries are less relevant as background for the current study on the TASER.

[4] Duff and McCaffrey (2001) suggested that variance in EI-related injuries may be explained by individual-level differences in physical health, psychosocial adjustment, gender, education, and pre-morbid characteristics (see also Cherington 1995; Daniel et al. 1985).

of cognitive functioning, and reported that impairment was evident across all eight domains (although it was most common in memory and attention).[5]

Miranda rights, waiver, and impairment

The legal questions surrounding the TASER and cognitive impairment have centered on *Miranda* rights. In *Miranda v. Arizona* (384 U.S. 436, 1966), the Supreme Court stated that any interrogation of a suspect would be presumed involuntary (and the statements inadmissible in court) unless the police had advised the defendant of his or her constitutional rights. These *Miranda* rights consist of five components: (1) the right to silence; (2) use of any statements against the suspect; (3) the right to counsel; (4) access to counsel for indigent suspects; and (5) assertion of rights (and termination of questioning) at any time (Rogers et al. 2007a, b). The Supreme Court affirmed the *Miranda* ruling in *Dickerson v. United States* (530 US 428, 2000), stating that the warnings are constitutional in origin and have "become embedded in routine police practice." The Court has been equally clear that a waiver of *Miranda* rights must be voluntary, knowing, and intelligent (see *Colorado v. Spring*, 479 US 564, 1986), and that the burden is on the State to prove that a waiver has met this standard (DeClue 2007). The voluntariness issue centers on the waiver being a "free and deliberate choice" without coercion or intimidation (*Colorado v. Spring* 1987, 573). A knowing waiver refers to the individual's comprehension of the rights, while the intelligence component focuses on the person's consideration of the options available and the consequences of a waiver (Frumkin 2000; Greenfield and Witt 2005).

In determining whether a *Miranda* waiver is valid, the Court has imposed a case-by-case strategy based on the "totality of the circumstances." No single factor automatically invalidates a waiver, nor are there specific scores or cutoffs that are recognized by the courts as baselines for waiver assessment (Oberlander and Goldstein, 2001). However, in *Coyote v. U.S.* (380 F.2d 305, 1967), the Court did identify a list of relevant factors to consider (e.g., intelligence, mental illness). Greenfield and Witt (2005: 476) noted that the knowing and intelligent aspects of a *Miranda* waiver can be violated when a suspect is "…cognitively impaired, confused, intoxicated, or otherwise possibly not fully mentally competent" (see also Cooper and Zapf 2008; Rogers et al. 2007b). In *Townsend v. Sain* (372 US 293, 1963), the Court ruled that statements to police are inadmissible in court unless they are "the product of a rational intellect and a free will." The 9th Circuit Court subsequently applied this standard to cases where the suspect is mentally ill, or under the influence of drugs or alcohol (*Gladden v. Unsworth*, 396 F 2d 373, 1968).

Relevance of the electrical injury literature for police use of CEDs

To date, no identified study has empirically examined whether the TASER may cause changes in cognitive functioning. Given the emersion of the TASER in policing, the absence of research in this area is troubling (Lim and Seet 2009). This knowledge gap raises serious concerns for the questioning of suspects who have received a TASER

[5] The eight domains were overall neuropsychological functioning, intelligence, attention/concentration, speech/language, sensory/motor, visual motor, memory, and executive functioning. They also examined potential links between EI and personality/mental disorders (i.e., psychopathology and neurosis) and found that 70 % of studies indicated a connection, most commonly for depression.

exposure, as it is unclear if the device affects a person's ability to voluntarily, knowingly, and intelligently waive their *Miranda* rights. The current study represents a first step in examining this important question.

Methodology

The current study was conducted at the San Bernardino County (CA) Sheriff's Training Center over a 2-week period, from April 24 to May 2, 2012, when the academy recruits received their instruction on use of the TASER (which includes a TASER exposure). The training class was divided into two sections (each with about 15 recruits), with one section receiving their TASER training in the last week of April and the other section receiving the training in the first week of May. On the morning of the training days when TASER exposures were scheduled, the authors presented to the recruits a full discussion of informed, voluntary consent regarding participation in the cognitive functioning study. This discussion focused on the purpose of the study, the potential risks and benefits, voluntariness, and different aspects of the testing protocol. The researchers then left the room and returned an hour later to answer any remaining questions and to collect the signed consent forms. A total of 32 police recruits agreed to participate in the study (out of 37 total recruits), but because of time and resource constraints, only 21 recruits were subsequently selected as research participants (e.g., on a "first-come first-serve" basis).[6] Approximately 25 % of the final sample were female (5 of 21 recruits). Participants' race was not recorded, nor was exact age. However, nearly all of the recruits were between the ages of 21 to 30.

Study participants were asked to complete a battery of cognitive tests at three points in time: *Pre-test*, approximately 3–4 h prior to TASER exposure (to establish baseline scores); *Post-test 1*, within 5 min following TASER exposure; and *Post-test 2*, approximately 24 h following TASER exposure. The battery of tests, selected through consultation with the project's Advisory Board, are well-established, validated, and reliable tests that measure a range of cognitive dimensions such as memory, concentration, speed of new learning, and motor function (see Appendix A for more detail).[7] The battery includes:

- *Subjective State Scale*: Measures self-reported difficulties in concentration and memory, and levels of perceived anxiety and feeling overwhelmed (scale of 0–10

[6] The authors could only staff two testing rooms for the study (e.g., only two recruits could be tested at the same time). Moreover, the pilot study was incorporated into the two-day training curriculum involving the TASER, which limited the authors' ability to accommodate additional recruit volunteers (e.g., recruits had other responsibilities).

[7] The selection of tests was also influenced by prior research on electrical injuries, as well as practical constraints (e.g., a comprehensive battery of tests that could be administered within a 20-min period of time). The project Advisory Board includes two clinical neuropsychologists (one with expertise in electrical injuries), a cognitive psychologist, two physicians, an attorney, and a Lieutenant with a police department in the state of Arizona. One of the neuropsychologists provided a half-day training session to the research team on the administration and scoring of the tests. The team also carried out a half-day practice session with college students. The cognitive psychologist was present for both testing sessions in San Bernardino. All cognitive testing sessions were video recorded and audited for accuracy and consistency by the cognitive psychologist.

with 0 being none and 10 being severe; for example, recruits were asked, "How would you rate your level of feeling overwhelmed right now? 0–10 with 0 meaning you are in complete control and 10 meaning you feel severely overwhelmed and you are not sure what to do next.").

- *Hopkins Verbal Learning Test* (HVLT): Measures verbal learning and memory by asking the respondent to recall a set of 12 words in three separate, consecutive trials (e.g., repeating back the words after the tester has read them aloud on three separate occasions); there is also a delayed recall component where the respondent is asked to recall the words approximately 20 min later, and a recognition component where the tester reads a separate list of words and asks the respondent to indicate "yes or no" if he/she believes each specific word was on the original list (there are 24 words on this recognition list, including the 12 original words).[8]
- *Digit Span Subtest*: Measures short-term auditory memory and concentration by asking the respondent to repeat a list of numbers that are read aloud, both in the same order as they are read (Digit Span Forward) and in reverse (Digit Span Backward).[9]
- *Digit Symbol Subtest*: Measures processing speed that is affected by motor coordination, short-term memory, and visual perception by asking the respondent to review nine digit–symbol pairs, and then to write down the symbols that correspond to a long list of digits as fast as possible over 2 min.[10]
- *Trail Making Test A and B*: Measures visual search abilities, scanning, speed of processing, mental flexibility, and executive functions by asking respondents to, as quickly as possible, connect 25 circles distributed on a piece of paper: Part A has these circles numbered 1 through 25; Part B alternates between numbered and lettered circles.[11]
- *Halstead Finger Tapping Test*: Measures motor functioning by asking respondents to press down a "tapper" with their index finger as many times as possible over a 10-s time period; respondents are asked to complete this task 5 times with each hand (starting with their dominant hand in a 3, 3, 2, 2 sequence).[12]

Because most of the cognitive tests are typically used for diagnostic purposes at one point in time, rather than longitudinally, the authors were concerned about the potential for learning effects across repeated measures of the same test. Therefore, we used alternate forms of one of the three cognitive tests where learning effects might be expected (Hopkins Verbal Learning Test), but did not use alternate forms for the other

[8] For validation and reliability of the HVLT, see: Brandt (1991), Brandt and Benedict (2001), Delis et al. (1987), Rasmusson et al. (1995), and Shapiro et al. (1999).
[9] For validation and reliability of the Digit Span test, see: Elwood and Griffin (1972), Gray (2003), Moldawsky and Moldawsky (1952), Werheid et al. (2002), and Weschler (1945).
[10] For validation and reliability of the Digit Symbol test, see: Elwood and Griffin (1972), Kreiner and Ryan (2001), and Ryan et al. (2000).
[11] For validation and reliability of the Trail Making test Parts A and B, see: Fals-Stewart (1992), Spreen and Strauss (1998), and Tombaugh (2004).
[12] For validation and reliability of the Halstead Finger Tapping test, see: Goldstein and Sanders (2003), Johnson and Prigatano (2000), and Prigatano and Wong (1997).

two tests (Digit Span and Trail Making). This was done, in part, to help determine the need for alternate forms during the randomized trial.

Each wave of cognitive tests lasted approximately 20 min. The researchers were divided into testing teams in two separate rooms. Each team was composed of two testers and a room coordinator who escorted recruits in and out of the room, supervised the testing process, and operated the video recorder. Shortly after completion of the informed consent procedure, 3–4 h before TASER exposure, recruits were escorted into the testing rooms one at a time for baseline testing. Later in the afternoon, recruits—as part of their academy training—were given a standard TASER exposure in the back, at a distance of seven feet.[13] The barbs were removed, and then recruits were immediately escorted into a testing room. Post-exposure testing began, on average, 3 min after the TASER exposure. After testing was complete, the recruit was escorted out of the room. The process was repeated for the 21 research participants, alternating among the testing rooms. The research team returned the following day and the recruits were given the same battery of cognitive tests again. Recruits were assigned to the same testing team for each administration. Each of the 21 recruits completed both the pre-test and post-test 1 measures, and 20 of the 21 recruits completed post-test 2 the following day (for a total of 62 separate test administrations over the three waves).[14]

Analysis

There are two primary comparisons of interest. The first is a comparison of recruits' cognitive test scores from baseline to post-test 1. Of particular interest is whether there are any statistically significant changes in cognitive scores immediately following TASER exposure. The second comparison of interest involves an examination of scores from baseline to post-test 2, the following day. This comparison provides insights on the duration of any changes in cognition that are documented in the first set of analyses (e.g., were reductions short-term, or were they still evident 24 h later?). Comparisons across testing points for each of the cognitive measures were carried out with paired samples t tests, and effect sizes were determined based on Glass's Lambda (Δ).

Results

Comparison 1: baseline to post-test 1 (immediately after TASER exposure)

Table 1 summarizes the comparison of cognitive test scores from baseline to post-test 1. The first two columns include a description of each cognitive test and the cognitive dimension that it measures. The third column provides significance levels based on paired samples t-tests, and the fourth column denotes relevant t-statistics and standard

[13] The authors did not ask the training academy staff to change the nature of the TASER exposure. The exposure in the back from seven feet is standard for the training setting. Exposures in the field are much more varied in terms of location and distance.

[14] One recruit was unavailable for post-test 2 because of logistical constraints associated with the training schedule.

Table 1 Paired samples *t* tests comparing baseline to post-test 1

Cognitive test	What it measures	Statistical significance	t(SD)	Size of difference	Effect size (Glass's Δ)
Subjective rating scale: *concentration*	Difficulty Concentrating (0–10)	$p<0.001$***	3.73(1.99)	Pre=0.76; Post1=2.38	1.55
Subjective rating scale: *memory*	Difficulty with Memory (0–10)	$p<0.01$**	2.77(1.02)	Pre=1.00; Post1=1.62	0.69
Subjective rating scale: *anxiety*	Feeling Anxiety (0–10)	$p<0.05$*	−2.07(2.21)	Pre=2.57; Post1=1.57	0.47
Subjective rating scale: *Overwhelmed*	Feeling Overwhelmed (0–10)	$p<0.05$*	2.45(1.96)	Pre=0.67; Post1=1.71	0.94
Hopkins verbal learning (Trials 1–3)	Verbal Learning; Short-term Memory (0–36)	$p<0.001$***	−5.94(3.16)	Pre=25.81; Post1=21.71	0.94
Delayed recall test (HVLT)	Verbal Learning; Delayed Recall (0–12)	$p<0.001$***	−6.15(1.63)	Pre=8.62; Post1=6.43	0.87
Recognition test (HVLT)	Word Recognition (# Errors)	$p<0.05$*	2.39(1.83)	Pre=1.48; Post1=2.43	0.58
Digit span (Forward)	Concentration; Memory (0–16)	—	0.69(1.58)	Pre=10.76; Post1=11.00	0.11
Digit span (Backward)	Concentration; Memory (0–14)	$p<0.01$**	2.85(1.69)	Pre=5.95; Post1=7.00	0.56
Digit symbol	Speed of New Learning (# symbols coded)	$p<0.001$***	8.07(6.84)	Pre=86.95; Post1=99.00	1.24
Trail making test (Part A)	Concentration; Problem Solving (# seconds)	$p<0.001$***	−4.53(4.89)	Pre=23.89; Post1=19.05	0.89
Trail making test (Part B)	Concentration; Problem Solving (# seconds)	$p<0.001$***	−3.76(11.24)	Pre=57.40; Post1=48.18	0.79
Halstead finger tapping (Right mean)	Motor Function (# taps)	$p<0.01$**	2.70(5.79)	Pre=50.77; Post1=54.18	0.52
Halstead finger tapping (Left mean)	Motor Function (# taps)	$p<0.01$**	3.63(3.78)	Pre=47.94; Post1=50.93	0.57

deviations. The fifth and sixth columns describe the size of the difference (i.e., mean difference in scores) and the effect size.

Subjective ratings The recruits reported experiencing significantly more difficulty with concentration and memory immediately following TASER exposure ($p<0.001$ and $p<0.01$, respectively). Recruits also reported feeling more overwhelmed at post-test 1, compared to their baseline measures ($p<0.05$). Alternatively, recruits reported significantly less anxiety following TASER exposure ($p<0.05$), compared to their baseline measures.

Hopkins Verbal Learning Test (HVLT) Table 1 shows statistically significant reductions in the recruits' cognitive scores in all three components of the HVLT, following TASER exposure. With regard to trials 1–3, recruits learned an average of 25.81 words (out of 36 total) at baseline, compared to 21.71 words at post-test 1 ($p<0.001$). On the delayed recall test, the subjects were able to recall an average of 8.62 words (out of 12 total) at baseline, compared to 6.43 words at post-test 1 ($p<0.001$). And for the recognition test, recruits made an average of 1.48 mistakes (false positives or negatives) during baseline, compared to 2.43 mistakes at post-test 1 ($p<0.05$). The effect sizes for these changes in cognitive scores were moderate to large (0.94, 0.87, and 0.58).

Digit Span, Digit Symbol and Trail Making (A and B) Recruits showed statistically significant improvements in their scores on the Digit Span (Backward) and on the Digit Symbol ($p<0.01$ and $p<0.001$, respectively). Scores on the Digit Span (Forward) did not change notably. Similarly, recruits also showed significant improvement in their test times to complete both versions of the Trail Making tests (A and B both $p<0.001$).

Halstead Finger Tapping Test Table 1 also shows the scores for both dominant and non-dominant hands (e.g., right and left) on the Finger Tapping test. Recruits showed improvement from baseline to post-test 1 ($p<0.01$ for both hands).

Comparison 2: baseline to post-test 2 (1 day after TASER exposure)

Table 2 shows the comparison of cognitive test scores from baseline to post-test 2.[15]

Subjective ratings From baseline to post-test 2, there were no differences in recruits' self-reported measures of difficulty in concentration and memory, as well as their degree of feeling overwhelmed. These findings suggest that recruits had returned to their baseline levels of these subjective measures by the next day. There is a significant reduction from baseline to post-test 2 with regard to their reported anxiety level. This finding may reflect the high levels of anxiety experienced by recruits prior to TASER exposure (and the relief they felt afterwards).

Hopkins Verbal Learning Test (HVLT) From baseline to post-test 2, there were no statistically significant differences in scores on any of the components of the HVLT. Given the substantial declines in performance reported in Table 1, the results from Table 2 suggest that by the following day recruits had returned to their baseline levels of performance on this measure.

Digit Span, Digit Symbol, and Trail Making (A and B) Recruits continued to show statistically significant improvement on the Digit Span (Forward and Backward) and Digit Symbol tests ($p<0.01$, $p<0.001$, $p<0.001$, respectively), as well as the Trail Making (A and B) tests (both $p<0.001$). These findings suggest that performance on these measures may be particularly susceptible to test–retest effects, as recruits "learned" how to perform better with each administration.

[15] Recall that one of the recruits did not complete the post 2 testing. As a result, the findings in Table 2 are based on analyses with 20 cases instead of 21. This explains why the pre-test scores in the "size of difference" column are different in Tables 1 and 2.

Table 2 Paired samples *t* tests comparing baseline to post-test 2

Cognitive test	What it measures	Statistical significance	t(SD)	Size of difference	Effect size (Glass's Δ)
Subjective rating scale: *concentration*	Difficulty Concentrating (0–10)	—	0.77(1.45)	Pre=0.75; Post2=1.00	0.07
Subjective rating scale: *memory*	Difficulty with Memory (0–10)	—	0.24(0.94)	Pre=0.95; Post2=1.00	0.06
Subjective rating scale: *anxiety*	Feeling Anxiety (0–10)	$p<0.01$**	−2.87(1.71)	Pre=2.55; Post2=1.45	0.50
Subjective rating scale: *overwhelmed*	Feeling Overwhelmed (0–10)	—	0.96(1.16)	Pre=0.70; Post2=0.95	0.22
Hopkins verbal learning (Trials 1–3)	Verbal Learning; Short-term Memory (0–36)	—	0.45(5.01)	Pre=25.85; Post2=26.35	0.11
Delayed recall test (HVLT)	Verbal Learning; Delayed Recall (0–12)	—	−2.01(2.56)	Pre=8.60; Post2=7.45	0.45
Recognition test (HVLT)	Word Recognition (# Errors)	—	−1.45(1.23)	Pre=1.55; Post2=1.15	0.24
Digit span (Forward)	Concentration; Memory (0–16)	$p<0.01$**	3.56(1.51)	Pre=10.70; Post2=11.90	0.56
Digit span (Backward)	Concentration; Memory (0–14)	$p<0.001$***	4.00(1.84)	Pre=5.90; Post2=7.55	0.86
Digit symbol	Speed of New Learning (# symbols coded)	$p<0.001$***	11.62(6.87)	Pre=86.80; Post2=104.65	1.79
Trail making test (Part A)	Concentration; Problem Solving (# seconds)	$p<0.001$***	−5.37(4.89)	Pre=24.36; Post2=18.49	1.14
Trail making test (Part B)	Concentration; Problem Solving (# seconds)	$p<0.001$***	−6.99(10.11)	Pre=56.49; Post2=40.68	1.42
Halstead finger tapping (Right mean)	Motor Function (# taps)	—	0.65(5.91)	Pre=50.51; Post2=51.37	0.13
Halstead finger tapping (Left mean)	Motor Function (# taps)	—	1.37(3.99)	Pre=47.62; Post2=48.84	0.24

Halstead Finger Tapping Test The recruits' post-test 2 scores on the Halstead Finger Tapping Test were not significantly different from their baseline scores. This suggests that the initial improvement immediately following TASER exposure (reported in Table 1) is likely not a result of learning effects (or else scores would have continued to improve). The reason for the short-term improvement is unclear, though one potential explanation involves the adrenalin that recruits experience after TASER exposure (which may have boosted their performance on this motor function test).[16]

[16] All of our cognitive tests were administered by two different teams of researchers. We have tested for statistically significant differences in the cognitive measures between the two research teams. There were too many significance tests involved in these analyses to present in a table format: 105 significance tests comparing the two different research teams at each data point (i.e., pre-test, post-test 1, and post-test 2). Only two (2) of the 105 tests showed significant differences between the two research teams. The teams showed significant differences on Trial 2 of Hopkins and on the cumulative Hopkins Trials 1–3.

Discussion

Summary of findings

Three important findings emerged from the current study. First, recruits experienced statistically significant reductions in several measures of cognitive functioning following TASER exposure. Specifically, recruits experienced statistically significant declines in cognitive performance on all three components of the Hopkins Verbal Learning Test. Recruits also demonstrated these reductions through the self-reported subjective ratings. The effect sizes for these reductions were moderate to large, despite the small sample size. Taken together, these findings suggest that the TASER may indeed produce deficits in some dimensions of cognitive functioning. These potential effects clearly warrant additional empirical study. If these effects are replicated in additional studies and are severe enough to impair an individual's ability to understand and waive *Miranda* rights, the implications for police policy and practice could be profound. Results could influence how and when police read *Miranda* rights to suspects who have received a TASER exposure. Also, the potential for the TASER to produce cognitive deficits may influence police departments' decisions to equip their officers with the device, as well as policy guiding when and against whom the device should be deployed (e.g., where on the force continuum). These questions are especially important given the diffusion of the TASER in American law enforcement (deployed by nearly two-thirds of all departments) and its increasing use in the field against citizens (e.g., an estimated 1.9 million uses).

The second major finding involves the improved recruit performance on several of the tests from baseline to post 1 and 2. Specifically, recruits experienced significant improvements in performance on the Digit Span (Backward and Forward), Digit Symbol, and the Trail Making (A and B) tests. The authors believe that the improved test performance may be the result of learning effects (test–retest) and/or reduced anxiety levels (e.g., performance improved after the exposure because the anxiety-inducing event had already occurred). To some extent, the test–retest learning effects were anticipated, and, in fact, the authors used different versions of the Hopkins Verbal Learning Test as a control. However, the size of the learning effects with the other tests was unexpected, and the effects continued to increase at each data collection point. For example, the mean score on the Trail Making B test was 57.40 s at baseline, 48.18 s at post 1, and 40.68 s at post 2. Moreover, it is possible that the learning effects may be masking deficits in performance caused by the TASER exposure (e.g., deficits were "invisible" because of the learning effects). This possibility highlights the importance of controlling for learning effects and anxiety levels in the larger study.

The third finding involves the comparison of test scores from baseline to post-test 2, which captures the duration of the changes identified immediately after TASER exposure. When recruits were tested the following day, all of the reductions in scores on the HVLT, as well as subjective ratings of memory, concentration, and feeling overwhelmed, had disappeared. Recruits had returned to their baseline levels. This finding suggests that changes in cognitive functioning are likely to be short-term and do not persist beyond 24 h.

Conceptual, methodological, and operational issues

The current study suffers from a number of limitations, most notably from the small number of participants, the lack of a comparison group, and the convenience-style sampling approach. Nevertheless, the pilot study allowed the authors to wade cautiously into the mostly uncharted waters of social science research involving risk to subjects.[17] Moreover, the results from the study serve as an important backdrop for consideration of a number of important conceptual, methodological, and operational issues related to this line of research. These include the generalizability of the study sample, the relevance of the cognitive tests for questions surrounding *Miranda* rights and waiver (i.e., construct validity), and the optimal testing protocols to capture the nature, prevalence, and duration of cognitive deficits following TASER exposure.

Generalizability of the study population The police recruits in the current study were physically, psychologically, and cognitively healthy. Though the authors did not assess recruits' health and wellness, the very fact that they had successfully passed through the rigorous screening protocols employed by the Sheriff's Department underscores their fitness, physical and otherwise. Similarly, in the RCT, the authors will employ rigorous screening protocols to insure that research participants are free from any health-related problems. The health of participants in these studies stands in stark contrast to the poor health of individuals who receive TASER exposures in "real-life" encounters with police (White and Ready 2009, 2010). Individuals who are "tased" by police are often under the influence of drugs or alcohol, are mentally ill and in crisis, and have a number of serious medical and psychological conditions (NIJ 2011; White and Ready 2007, 2010). These health disparities raise concerns about the generalizability of the pilot study findings (as well as the findings from the larger RCT).

There are several counterpoints which mitigate this concern, however. First and foremost, individuals who participate in a research study must not be subjected to any risk of harm as a result of their participation. This is a core principle of scientific inquiry (i.e., do not harm). Prior research on deaths following TASER exposure clearly identify substance use/abuse, mental illness, and pre-existing physical and psychological conditions as risk factors for an adverse reaction (White et al. 2013). As a result, ethical standards demand that the authors recruit a healthy participant pool for the current study and the RCT. Second, by restricting participation in the study to healthy individuals, the authors are able to minimize the potential confounding explanations for any documented deficits in cognitive functioning following TASER exposure. For example, if the pilot study had included intoxicated, high, or mentally ill individuals, there would be no way to disentangle the effects of the TASER on cognitive functioning from the effects of the alcohol, illicit drugs or mental illness. In a study with healthy participants, cognitive deficits that occur can more confidently be attributed to the TASER exposure, rather than alternative factors (particularly in the RCT).

[17] The NIJ-funded project has been reviewed and received approval from the Western Institutional Review Board (WIRB Pr. No.: 20120385; WIRB Study No.: 1131198). The authors received IRB approval on April 4, 2012. As part of the IRB protocol, the authors were prepared to return to San Bernardino for additional testing in the weeks following the pilot study, if deficits had persisted beyond the 24-h mark.

Relevance of the cognitive test results for Miranda rights and waiver The pilot study results documented temporary reductions in performance on several tests of cognitive functioning (following TASER exposure). The cognitive tests employed in this study are valid and reliable assessments of memory, attention, speed of learning, etc., but the content of the tests are not at all related to the substance and content of the *Miranda* warnings (e.g., right to remain silent, right to an attorney, etc.). This raises the question of whether the deficits observed in the pilot study are relevant for a person's ability to listen to the *Miranda* warnings, and make a knowing, intelligent, and voluntary waiver of their rights. That is, can decreased performance on the Hopkins Verbal Learning Test be viewed as a proxy for reduced ability to understand and waive *Miranda* rights? This question involves construct validity.

The authors have devised a two-phase approach to consider the relevance of the cognitive tests for *Miranda* waiver. The first phase centers on determining whether a TASER exposure produces cognitive deficits at all. For the first phase, the authors have drawn on the literature examining electrical injury (Duff and McCafferey 2001; Pliskin et al. 2006) to develop testing protocols that will capture deficits in different dimensions of cognitive functioning—if they occur. If deficits are observed, the authors can also document the prevalence, onset, and duration of those effects. For example, in the pilot study, the authors were able to determine that recruits had returned to their baseline within 24 h. Moreover, the cognitive tests used in the pilot study have been validated and tested across a number of special populations (e.g., there are standardized scores for Alzheimer's patients, mentally retarded persons, etc.). The authors will be able to compare the test scores from the larger study to the standardized test scores of other special populations. For example, how do HVLT scores among individuals receiving a TASER exposure compare with HVLT scores among patients with stage 4 and stage 5 Alzheimer's? These comparisons will lay a foundation for understanding the severity of any documented deficits following TASER exposure.

If the authors document cognitive deficits in the larger study, they will then turn to consideration of the implications of those deficits for individuals' ability to make voluntary, knowing, and intelligent *Miranda* waivers. A large body of literature has explored the understanding of *Miranda* rights among vulnerable populations, including juveniles, psychiatric patients, and mentally retarded individuals (e.g., Cooper and Zapf 2008; Rogers et al. 2007a), and there are a number of instruments specifically designed to capture understanding of *Miranda* rights (e.g., Grisso 1998). Pending results from the planned RCT, the authors will conduct subsequent investigations that specifically test the impact of TASER exposure on individuals' ability to complete standardized assessments of comprehension of *Miranda* rights.

Optimal testing protocols In addition to demonstrating the need for alternate test versions (to reduce learning effects), the pilot study also provided important insights regarding the sequence and timing of testing protocols for the larger RCT. For example, the authors shared the results of the pilot study with the Advisory Board, and the neuropsychologists suggested that the authors add an additional test that captures auditory comprehension (e.g., ability to listen to a short story and correctly answer questions about the story). Also, the results from the pilot study indicated that cognitive deficits had disappeared by the 24-h mark. In order to capture a more precise picture of the effects of the TASER, the authors added a 1-h post-exposure test point in the larger study. This new test point will offer a clearer picture on the duration of potential changes in cognitive functioning produced by the TASER (i.e., do the effects last longer than 1 h?).

Last, the pilot study results demonstrated the balance between statistical power, sample size, and repeated measures. In a repeated measures design, researchers often boost their statistical power by adding additional data collection points. Given the learning effects that were observed in the pilot study, this method of boosting power is less than optimal. Moreover, the authors also noticed signs of test fatigue, as recruits were asked to complete the same battery of tests three times in a 24-h window. As a result, in the larger study, the authors modified the data collection protocols by creating longer time periods between test administrations, by reducing the number of test administrations (originally seven, reduced to six), and by boosting the sample size for the RCT (originally $n=100$, amended to $n=150$).

Conclusions

Though conclusions based on the results from the current study should be drawn with caution, the findings do offer important, preliminary insights into the potential effects of the TASER on cognitive functioning. The extent to which the larger literature on electrical injury is relevant for TASER exposure remains unknown, but the early results suggest that there may be an association between TASER exposure and cognitive impairment. Further study with more rigorous methodologies is required. Moreover, the current study provides an important foundation for the authors' larger RCT. The pilot study has helped to ensure that the larger study will be carried out in a manner that minimizes risk, offers important findings on the effects of the TASER on cognitive functioning, and, if deficits occur, enhances our understanding of the nature, severity, and duration of those effects. The questions being explored in this line of research are weighty, involving constitutionally protected rights of the accused, police use of force against citizens, and previously unexamined effects of the TASER on the human body. This line of research has potential implications for police policy and practice governing use of force, arrest, and the reading of *Miranda* rights; for courts which must rule on legal arguments involving TASER exposure and *Miranda* waiver; and, more generally, for our understanding of the cognitive effects of a device that has been used by police on nearly two million citizens.

Appendix A: Descriptions of the cognitive tests

Digit Symbol

About the test

The Digit Symbol subtest, a component of the Wechsler Adult Intelligence Scale (WAIS), is a measure of processing speed that is affected by motor coordination, short-term memory, and visual perception (Kreiner & Ryan, 2001; Kaplan, Fein, Morris, & Delis, 1991). The test is used to indicate functional decline in cognitive ability, as well as impaired brain functioning (Drachman, O'Donnell, Lew, & Swearer, 1990; Kreiner & Ryan, 2001). Scores are highly negatively correlated with age (−0.59, $p<0.01$) (Kreiner & Ryan, 2001), regardless of the study design (i.e. longitudinal or cross-sectional) or the education level of participants (Ryan, Sattler, & Lopez, 2000; Wieglos & Cunningham, 1999; Compton, Bachman, & Logan, 1997).

Administration

According to the National Institute of Mental Health funded website, Cognitive Atlas, the Digit Symbol test consists of nine digit-symbol pairs, followed by a set of digits. Participants are then asked to write down the symbols that correspond to the digits in this list as fast as possible. Respondents are usually allotted 90 or 120 s to complete the task, and following completion the number of correct symbols is measured ("Task: Digit Symbol Coding Test," n.d.).

Validation/reliability

The reliability coefficient for the Digit Symbol subtest has been reported as high as 0.92 (with the automated version of the test having a coefficient of 0.97) (Elwood & Griffin, 1972). Internal validity does not seem to be affected by repeated testing, especially in older participants (Paolo & Ryan, 1994).

References

Compton, D. M., Bachman, L. D., & Logan, J. A. (1997). Aging and intellectual ability in young, middle-aged, and older educated adults: Preliminary results from a sample of college faculty. *Psychological Reports*, *81*, 79-90.

Drachman, D. A., O'Donnell, B. F., Lew, R. A., & Swearer, J. M. (1990). The prognosis is Alzheimer's Disease: "How far" rather than "how fast" best predicts the course. *Archives of Neurology*, *47*, 851-856.

Elwood, D. L., & Griffin, H. R. (1972). Individual intelligence testing without the examiner: Reliability of an automated method. *Journal of Consulting and Clinical Psychology*, *38*(1), 9-14.

Kaplan, E., Fein, D., Morris, R., & Delis, D. C. (1991). *WAIS-R as a neuropsychological instrument*. San Antonio, TX: The Psychological Corporation.

Kreiner, D. S., & Ryan, J. J. (2001). Memory and motor skill components of the WAIS-III digit symbol-coding subtest. *The Clinical Neuropsychologist*, *15*(1), 109-113.

Ryan, J. J., Sattler, J. M., & Lopez, S. J. (2000). Age effects on Wechsler Adult Intelligence Scale-III subtests. *Archives of Clinical Neuropsychology*, *15*, 311-317.

Task: Digit/Symbol Coding Test. (n.d.). Retrieved from Cognitive Atlas: http://cognitiveatlas.org/task/id/tsk_4a57abb949a25

Wieglos, C., & Cunningham, W. R. (1999). Age related slowing on the Digit Symbol Task: Longitudinal and cross-sectional analyses. *Experimental Aging Research*, *25*, 109-120.

Digit Span

About the test

Also known as the Memory Span test, the Digit Span subtest of the WAIS-IV (as it is called when numbers are used) is a test of short-term rote auditory memory (Sattler & Ryan, 2009). This subtest is comprised of two parts: Digit Span Forward and Digit Span Backward (Conklin, Curtis, Katsanis, & Iacono, 2000; Weschler, 1945). Weschler (1945) developed this subtest as one of seven tests in his Memory Scale. The scale was designed to be a "rapid, simple, and practical memory examination" (Weschler, 1945, p. 87).

Administration

Weschler (1945) gives instructions on how to administer this test. The following details the digits forward portion:

> Say: "I want to see how well you can pay attention. I am going to say some numbers and when I am through I want you to say them right after me. Listen." Begin with 4 digits forward, or at [a] point where the patient will undoubtedly get [the] series correct. Continue upward until both sets of a series are successively failed…
>
> …*Scoring* – Score is maximum number of digits repeated correctly; for example, if subject repeats 5 digits on either of 2 trials, his score is 5. *Maximum score – 8*. (p. 92)

The digits backward portion should be administered as follows, according to Weschler (1945):

> Always begin with a series of 3, after illustrating this: "I want to see how well you can hold numbers in your mind. I am going to read to you a set of numbers and when I am through I want you to say them after me backward. For example: if I say 1, 9, 5, you should say (pause) 5, 9, 1." If subject does not get them correctly, say, "That was not quite right, you should have said… Now listen again and remember, say them after me backward. Are you ready? Give following series. If subject gets first series of a set correctly, continue with next higher series; if he fails give second trial…
>
> …*Scoring* – Score is maximum number of digits which subject can repeat backward… *Maximum score – 7*. N.B. If subject fails on repetition of 3 digits backward, he may be given 2 digits, and allowed a score of 2, if he passes either of 2 trials. (p. 92)

Validation/reliability

Manual administration of the Digit Span test yields a reliability of 0.84 (automated administration is less reliable at 0.65) (Elwood & Griffin, 1972). Digit span tasks (including Weschler's version and various iterations) are considered to have high validity and specificity for diagnostic measures (Gray, 2003; Werheid, et al., 2002). Further, the Digit Span test has also been shown to be a valid indicator of situational anxiety, with anxiety producing poor results on the test (Moldaswky & Moldawsky, 1952).

References

Conklin, H. M., Curtis, C. E., Katsanis, J., & Iacono, W. G. (2000). Verbal working memory impairment in schizophrenia patients and their first-degree relatives: Evidence from the digit span task. *The American Journal of Psychiatry*, *157*(2), 275-277.

Elwood, D. L., & Griffin, H. R. (1972). Individual intelligence testing without the examiner: Reliability of an automated method. *Journal of Consulting and Clinical Psychology*, *38*(1), 9-14.

Gray, S. (2003). Diagnostic accuracy and test-retest reliability of nonword repetition and digit span tasks administered to preschool children with specific language impairment. *Journal of Communication Disorders*, *36*, 129-151.

Moldawsky, S., & Moldawsky, P. C. (1952). Digit span as an anxiety indicator. *Journal of Consulting Psychology*, *16*(2), 115-118.

Sattler, J. M., & Ryan, J. J. (2009). *Assessment with the WAIS-IV.* California: Jerome M. Sattler, Publisher, Inc.

Werheid, K., Hoppe, C., Thone, A., Muller, U., Mungersdorf, M., & von Cramon, D. Y. (2002). The Adaptive Digit Ordering Test: Clinical application, reliability, and validity of a verbal working memory test. *Archives of Clinical Neuropsychology*, *17*(6), 547-565.

Weschler, D. (1945). A standardized memory scale for clinical use. *The Journal of Psychology*, *19*, 87-95.

Trail-making

About the test

The Trail-Making test is a neuropsychological test that assesses visual search abilities, scanning, speed of processing, mental flexibility, and executive functions (Tombaugh, 2004, p. 203). Age and education are two factors that impact test performance, with age accounting for 34-38 % of the variance in trail-making (Tombaugh, 2004, p. 205).

Administration

According to Allen and Haderlie (2010), the Trail-Making test is administered in two parts, A and B. Both parts consist of 25 circles distributed on a piece of paper; part A has these circles numbered 1 through 25, while part B alternates between numbered and lettered circles. The participant is instructed to connect the circles in sequence as fast as possible. The score is the number of seconds required for completion of the test. The test administrator corrects errors as they are occurring, which impacts the test score (seconds until completion).

Validation/reliability

Tombaugh (2004) provides a stratification of norms (age and education) to be used when assessing test responses, which is supported by other literature and findings (Lezak, 1995; Mitrushina, Boone, & D'Elia, 1999; Spreen & Strauss, 1998). Reliability of this instrument is difficult to measure because the subject's performance may improve from practice effects (due to repeated administration) (Fals-Stewart, 1992). Alternate versions of this test are available for younger populations (e.g. color trails) (Allen & Haderlie, 2010).

References

Allen, D. N., & Haderlie, M. M. (2010). Trail-Making test. *Corsini Encyclopedia of Psychology.*

Fals-Stewart, W. (1992). An interrater reliability study of the trail making tests (parts a and b). *Perceptual and Motor Skills*, *74*, 39-42.

Lezak, M. D. (1995). *Neuropsychological assessment* (3rd ed.). New York: Oxford University Press.

Mitrushina, M. N., Boone, K. L., & D'Elia, L. (1999). *Handbook of normative data for neuropsychological assessment*. New York: Oxford University Press.

Spreen, O., & Strauss, E. (1998). *A compendium of neuropsychological tests*: *Administration*, *norms and commentary* (2nd ed.). New York: Oxford University Press.

Tombaugh, T. N. (2004). Trail making test a and b: Normative data stratified by age and education. *Archives of Clinical Neuropsychology*, *19*, 203-214.

Hopkins Verbal Learning Test (HVLT)

About the test

The HVLT, originally developed by Brandt (1991), is a test of verbal learning and memory. This test is useful for respondents when repeated testing is necessary (Brandt, 1991). The HVLT-R, developed by Brandt and Benedict (2001), comprises six alternate forms (each with a list of 12 nouns with four words drawn from each of three semantic categories); (Strauss, Sherman, & Spreen, 2006, p. 760). The HVLT-R includes three learning trials, a delayed recall trial (given without warning after a delay of 20-25 min), and a delayed recognition trial (Strauss et al., 2006, p. 760). The original HVLT did not include the delayed recall portion (Strauss et al., 2006, p. 760).

Administration

Excluding the delay interval, the test takes 15 min to administer (Strauss et al., 2006, p. 760). The examiner reads the word list and asks the respondent to verbally repeat the words (immediately and after a delay); the responses are recorded verbatim on a scoring sheet (Strauss et al., 2006, p. 760). The test can be purchased online at http://www4.parinc.com/Products/Product.aspx?ProductID=HVLT-R.

Validation/reliability

Brandt (1991) tested the interform reliability of the original HVLT; the six forms are highly intercorrelated. Rasmusson, Bylsma, and Brandt (1995) found the reliability of the HVLT to be moderately stable over time. The test-retest reliability of the HVLT is comparable to the California Verbal Learning Test (Delis, Kramer, Kaplan, & Ober, 1987). Shapiro, Benedict, Schretlen, and Brandt (1999) also found evidence to support the construct, concurrent, and discriminant validity of the HVLT.

References

Brandt, J. (1991). The Hopkins verbal learning test: Development of a new memory test with six equivalent forms. *Clinical Neuropsychologist*, *5*(2), 125-142.

Brandt, J., & Benedict, R. H. B. (2001). *Hopkins Verbal Learning Test-Revised*. Lutz, FL: Psychological Assessment Resources.

Delis, D. C., Kramer, J. H., Kaplan, E., & Ober, B. A. (1987). *California Verbal Learning Test*. New York: The Psychological Corporation.

Rasmusson, D. X., Bylsma, F. W., & Brandt, J. (1995). Stability of performance on the Hopkins Verbal Learning Test. *Archives of Clinical Neuropsychology*, *10*, 21-26.

Shapiro, A. M., Benedict, R. H. B., Schretlen, D., & Brandt, J. (1999). Construct and concurrent validity of the Hopkins Verbal Learning Test-Revised. *The Clinical Neuropsychologist*, *13*, 348-358.

Strauss, E., Sherman, E. M. S., & Spreen, O. (2006). *A compendium of neuropsychological tests*: *Administration*, *norms*, *and commentary* (3rd ed). New York: Oxford University Press.

Halstead Finger Tapping Test (Prigatano adaptation)

About the test

The Halstead-Reitan Neuropsychological Test Battery was one of the first recognized neuropsychological assessments used in the screening of neuropsychological impairments (Groth-Marnat, 2009, p. 486). One component, the Halstead Finger Tapping Test, is assessed here; the speed of finger tapping (after traumatic brain injury) has been related to impaired self-awareness (see e.g., Prigatano, 1999; Goldstein & Sanders, 2003). Many sources cite the usefulness of the Halstead Finger Tapping Test as a clinical neuropsychological measure (Johnson & Prigatano, 2000; Goldstein & Sanders, 2003; Lezak, 1995; Prigatano, 1999; Prigatano & Wong, 1997; Reitan & Wolfson, 2003; Spreen & Strauss, 1998).

Administration

A version of the Halstead Finger Tapping Test, utilized by Johnson and Prigatano (2000), asks the participants to tap their right hand for 15 s alternating with 15 s of rest. The task becomes more difficult during the course of the 150 s experiment (Johnson & Prigatano, 2000). A "finger tapping kit" can be purchased through PAR at http://www4.parinc.com/Products/Product.aspx?ProductID=FINGER_TAP.

Validation/reliability

The validity of the Halstead-Reitan Neuropsychological Test is recognized in the context of the entire battery (Goldstein & Sanders, 2003, p. 315). Validity of the individual tests is scarce, although normative information is available for the Finger Tapping Test (Goldstein & Sanders, 2003, p. 315). Further, reduced tapping speed is an indicator of several neuropsychological conditions (Goldstein & Sanders, 2003, p. 315). Reliability is also not thoroughly researched in neuropsychological assessment, as neuropsychological tests are often documenting recovery or deterioration (Goldstein & Sanders, 2003, p. 316).

References

Groth-Marnat, G. (2009). *Handbook of psychological assessment* (5th ed.). Hoboken, New Jersey: John Wiley & Sons, Inc.

Goldstein, G., & Sanders, R. D. (2003). Sensory-perceptual and motor function. In G. Goldstein, S. R. Beers, & M. Hersen (Eds.), *Comprehensive handbook of psychological assessment*: *Intellectual and neuropsychological assessment* (*volume 1*) (pp. 309-320). Hoboken, New Jersey: John Wiley & Sons, Inc.

Johnson, S. C., & Prigatano, G. P. (2000). Functional MR imaging during finger tapping. *Barrow Quarterly*, *16*(3), 37-41.

Lezak, M. D. (1995). *Neuropsychological Assessment*. New York: Oxford University Press.

Prigatano, G. P. (1999). Impaired awareness, finger tapping, and rehabilitation outcome after brain injury. *Rehabilitation Psychology*, *44*, 145-159.

Prigatano, G. P., & Wong, J. L. (1997). Speed of finger tapping and goal attainment after unilateral cerebral vascular accident. *Archives of Physical Medicine and Rehabilitation*, *78*, 847-852.

Psychological Assessment Resources. (2012). Finger Tapper (Adult/Adolescent). Retrieved from http://www4.parinc.com/Products/Product.aspx?ProductID=FINGER_TAP

Spreen, O., & Strauss, E. (1998). *A compendium of neuropsychological tests*: *Administration*, *norms and commentary* (2nd ed.). New York: Oxford University Press.

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References

Alpert, G. P., & Dunham, R. G. (2010). Policy and training recommendations related to police use of CEDs: Overview of findings from a comprehensive national study. *Police Quarterly, 13*(3), 235–259.

Alpert, G. P., Smith, M. R., Kaminski, R. J., Fridell, L. A., MacDonald, J., & Kubu, B. (2011). *Police use of force, TASERs and other less-lethal weapons*. Washington, DC: National Institute of Justice.

Barrash, J., Kealey, G. P., & Janus, T. J. (1996). Neurobehavioral sequelae of high voltage electrical injuries: Comparison with traumatic brain injury. *Applied Neuropsychology, 3*, 75–81.

Bozeman, W. P., Hauda, W. E., Heck, J. J., Graham, D. D., Martin, B. P., & Winslow, J. E. (2009). Safety and injury profile of conducted electrical weapons used by law enforcement officers against criminal suspects. *Annals of Emergency Medicine, 53*, 480–489.

Brandt, J. (1991). The Hopkins verbal learning test: Development of a new memory test with six equivalent forms. *Clinical Neuropsychologist, 5*(2), 125–142.

Brandt, J., & Benedict, R. H. B. (2001). *Hopkins Verbal Learning Test-Revised*. Lutz, FL: Psychological Assessment Resources.

Cherington, M. (1995). Central nervous system complications of lightning and electrical injuries. *Seminars in Neurology, 15*, 233–240.

Cooper, V. G., & Zapf, P. A. (2008). Psychiatric patients' comprehension of Miranda rights. *Law and Human Behavior, 32*, 390–405.

Crews, W. D., Barth, J. T., Brelsford, T. N., Francis, J. P., & McArdle, P. A. (1997). Neuropsychological dysfunction in severe accidental electrical shock: Two case reports. *Applied Neuropsychology, 4*, 208–219.

Daniel, M., Haban, G. F., Huctherson, W. L., Bolet, J., & Long, C. (1985). Neuropsychological and emotional consequences of accidental high-voltage electrical shock. *International Journal of Clinical Neuropsychology, 7*(2), 102–106.

DeClue, G. (2007). Oral Miranda warnings: A checklist and a model presentation. *The Journal of Psychiatry and the Law, 35*, 421–441.

Delis, D. C., Kramer, J. H., Kaplan, E., & Ober, B. A. (1987). *California Verbal Learning Test*. New York: The Psychological Corporation.

Duff, K., & McCafferey, R. (2001). Electrical injury and lightning injury: A review of their mechanisms and neuropsychological, psychiatric, and neurological sequelae. *Neuropsychological Review, 11*(2), 101–116.

Elwood, D. L., & Griffin, H. R. (1972). Individual intelligence testing without the examiner: Reliability of an automated method. *Journal of Consulting and Clinical Psychology, 38*(1), 9–14.

Fals-Stewart, W. (1992). An interrater reliability study of the trail making tests (parts a and b). *Perceptual and Motor Skills, 74*, 39–42.

Fish, R. (2000). Electrical injury, part II: Specific injuries. *Journal of Emergency Medicine, 18*(1), 27–34.

Frumkin, B. (2000). Competency to waiver Miranda rights: Clinical and legal issues. *Mental and Physical Disability Law Reporter, 24*(2), 326–331.

Goldstein, G., & Sanders, R. D. (2003). Sensory-perceptual and motor function. In G. Goldstein, S. R. Beers, & M. Hersen (Eds.), *Comprehensive handbook of psychological assessment: Intellectual and neuropsychological assessment (volume 1)* (pp. 309–320). Hoboken, New Jersey: John Wiley & Sons, Inc.

Gray, S. (2003). Diagnostic accuracy and test-retest reliability of nonword repetition and digit span tasks administered to preschool children with specific language impairment. *Journal of Communication Disorders, 36*, 129–151.

Greenfield, D. P., & Witt, P. H. (2005). Evaluating adult Miranda waiver competency. *Journal of Psychiatry and the Law, 33*, 471–489.

Grisso, T. (1998). *Instruments for assessing understanding and appreciation of Miranda rights*. Sarasota, FL: Professional Resource Press.

Ho, J. D., Miner, J. R., Lakireddy, D., Bultman, L. L., Heegaard, L., & Heegaard, W. G. (2006). Cardiovascular and physiologic effects of conducted electrical weapon discharge in resting adults. *Academic Emergency Medicine, 6*, 239–243.

Hooshmand, H. F., Radfar, F., & Beckner, E. (1989). The neurophysiological aspects of electrical injuries. *Electroencephalography, 20*(2), 111–120.

Hopewell, C. A. (1983). Serial neuropsychological assessment in a case of reversible electrocution encephalopathy. *Clinical Neuropsychology, 5*, 61–65.

Johnson, S. C., & Prigatano, G. P. (2000). Functional MR imaging during finger tapping. *Barrow Quarterly, 16*(3), 37–41.

Kreiner, D. S., & Ryan, J. J. (2001). Memory and motor skill components of the WAIS-III digit symbol-coding subtest. *The Clinical Neuropsychologist, 15*(1), 109–113.

Lim, E., & Seet, R. (2009). Taser usage and neurological sequelae. *The Journal of Emergency Medicine, 37*(2), 170–171.

Miller, L. (1993). *Toxic torts: Clinical, neuropsychological, and forensic aspects of chemical and electrical injuries* (pp. 6–17). January/February: The Journal of Cognitive Rehabilitation.

Moldawsky, S., & Moldawsky, P. C. (1952). Digit span as an anxiety indicator. *Journal of Consulting Psychology, 16*(2), 115–118.

National Institute of Justice. (2011). *Study of deaths following electro muscular disruption*. Washington, DC: National Institute of Justice.
Oberlander, L. B., & Goldstein, N. E. (2001). A review and update on the practice of evaluating Miranda comprehension. *Behavioral Sciences and the Law, 19*, 453–471.
Pasquier, M., Carron, P. N., Vallotton, L., & Yersin, B. (2011). Electronic control device exposure: A review of morbidity and mortality. *Annals of Emergency Medicine, 58*(2), 178–188.
Pliskin, N., Fink, J., Malina, A., Moran, S., Kelley, K., Capelli-Schellpfeffer, M., & Lee, R. (2006). The neuropsychological effects of electrical injuries: New insights. *Annals of the New York Academy of Sciences, 888*, 140–149.
Pliskin, N., Meyer, G. J., Dolske, M. C., Heilbronner, R. L., Kelley, K. M., & Lee, R. C. (1994). Neuropsychiatric aspects of electrical injury: a review of neuropsychological research. *Annals of the New York Academy of Sciences, 720*(1), 219–223.
Police Executive Research Forum (2009). *Comparing safety outcomes in police use-of-force cases for law enforcement agencies that have deployed Conducted Energy Devices and a matched comparison group that have not: A quasi-experimental evaluation*. Washington, DC: PERF.
Premalatha, G. D. (1994). Post traumatic stress disorder following an electric shock. *Medical Journal of Malaysia, 49*, 292–294.
Prigatano, G. P., & Wong, J. L. (1997). Speed of finger tapping and goal attainment after unilateral cerebral vascular accident. *Archives of Physical Medicine and Rehabilitation, 78*, 847–852.
Rasmusson, D. X., Bylsma, F. W. & Brandt, J. (1995). Stability of performance on the Hopkins Verbal Learning Test. Archives of Clinical Neuropsychology, 10, 21-26. Rogers, R., Harrison, K. S., Shuman, D. W., Sewell, K. W. & Hazelwood, L. L. (2007a). An analysis of Miranda warnings and waivers: Comprehension and coverage. Law and Human Behavior, 31, 177-192
Rogers, R., Harrison, K. S., Hazelwood, L. L., & Sewell, K. W. (2007a). Knowing and intelligent: A study of Miranda warnings in mentally disordered defendants. *Law and Human Behavior, 31*, 401–418.
Rogers, R., Harrison, K. S., Shuman, D. W., Sewell, K. W., & Hazelwood, L. L. (2007b). An analysis of Miranda warnings and waivers: Comprehension and coverage. *Law and Human Behavior, 31*, 177–192.
Ryan, J. J., Sattler, J. M., & Lopez, S. J. (2000). Age effects on Wechsler Adult Intelligence Scale-III subtests. *Archives of Clinical Neuropsychology, 15*, 311–317.
Shapiro, A. M., Benedict, R. H. B., Schretlen, D., & Brandt, J. (1999). Construct and concurrent validity of the Hopkins Verbal Learning Test-Revised. *The Clinical Neuropsychologist, 13*, 348–358.
Smith, M. R., Kaminski, R. J., Alpert, G. P., Fridell, L. F., MacDonald, J., & Kubu, B. (2009). *A multi-method evaluation of police use of force outcomes*. Washington, DC: National Institute of Justice.
Smith, M., Petrocelli, M., & Sheer, C. (2007). Excessive force, civil liability, and the Taser in the nation's courts: Implications for law enforcement policy and practice. *Policing: An International Journal of Police Strategies and Management, 30*(3), 398–422.
Spreen, O., & Strauss, E. (1998). *A compendium of neuropsychological tests: Administration, norms and commentary* (2nd ed.). New York: Oxford University Press.
Tombaugh, T. N. (2004). Trail making test a and b: Normative data stratified by age and education. *Archives of Clinical Neuropsychology, 19*, 203–214.
Varney, N. R., Ju, D., Sheperd, J. S., & Kealey, G. P. (1998). Long-term neuropsychological sequelae of severe burns. *Archives of Clinical Neuropsychology, 13*, 737–749.
Vilke, G. M., Bozeman, W., & Chan, T. (2011). Emergency department evaluation after conducted energy weapon use: Review of the literature for the clinician. *Journal of Emergency Medicine, 40*(5), 598–604.
Werheid, K., Hoppe, C., Thone, A., Muller, U., Mungersdorf, M., & von Cramon, D. Y. (2002). The Adaptive Digit Ordering Test: Clinical application, reliability, and validity of a verbal working memory test. *Archives of Clinical Neuropsychology, 17*(6), 547–565.
Weschler, D. (1945). A standardized memory scale for clinical use. *The Journal of Psychology, 19*, 87–95.
White, M., & Ready, J. (2007). The TASER as a less-lethal force alternative: Findings on use and effectiveness in a large metropolitan police agency. *Police Quarterly, 10*(2), 170–191.
White, M., & Ready, J. (2009). Examining fatal and nonfatal incidents involving the TASER: Identifying predictors of suspect death reported in the media. *Criminology and Public Policy, 8*(4), 865–891.
White, M., & Ready, J. (2010). The impact of the TASER on suspect resistance: Identifying predictors of effectiveness. *Crime & Delinquency, 56*(1), 70–102.
White, M., Ready, J., Riggs, C., Dawes, D. M., Hinz, A., & Ho, J. D. (2013). An incident-level profile of TASER device deployments in arrest-related deaths. *Police Quarterly, 16*(1), 85–112.
Zia Ul Haq, M., Prakash, R., Soy, A., Gupta, A., & Ahktar, S. (2008). Resolution of low voltage electrical injury induced psychosis with olanzapine. *Brain Injury, 22*(4), 361–364.

Court Cases

Colorado v. Spring (1986), 479 U.S. 157
Coyote v. United States (1967), 380 F.2d 305
Dickerson v. U.S. (2000), 530 US 428
Gladden v. Unsworth (1968), 396 F 2d 373
Miranda v. Arizona (1966), 384 U.S. 436
Townsend v. Sain (1963), 372 US 293
U.S. v. Mack (2009), No. 07–238, US District Court Middle District of Louisiana

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