Device Agnostic Digital Digit Symbol Substitution Test (DSST) for Use on Smartphones and Tablets

Xu M[1], Thorp E[2], Keylock LM[2], Lown P[3,4], Brooks N[5], Robin J[1], Cree F[2], Wragg E[2], Cormack F[2,6]

[1]Cambridge Cognition Ltd, Toronto, ON, Canada, [2]Cambridge Cognition Ltd, Cambridge, UK, [3]Department of Government, University of Essex, Colchester, UK, [4]Centre for Behavioural Science, University of Essex, Colchester, UK, [5]Department of Economics, University of Essex, Colchester, UK, [6]Department of Psychiatry, University of Cambridge, Cambridge, UK

The Methodological Issue Being Addressed

Investigating comparability of DSST data collected remotely using a smartphone device and in-person on an iPad to expand administration options for digitized cognitive tests across remote and in-clinic clinical trial settings.

Introduction

DSST is a widely used neuropsychological assessment examining cognitive domains including processing speed, associative learning, attention and executive function. It is a brief and objective test sensitive to cognitive impairment in a wide range of patient populations such as Alzheimer's disease, major depressive disorder, etc.

The traditional version is a written test with the main outcome measure being the number of correct patterns drawn by the participant within 90 seconds. Digital versions have been developed with automated scoring and richer measures, which provide a more efficient method of assessing cognition, as well as extending the opportunity for more frequent remote measurement for patients alongside self-report assessments such as in patients with depression.

This poster aims to investigate the comparability of digital DSST data collected remotely on a smartphone vs in-person using an iPad, reflecting extended use of digital assessment, to complement the previous work on comparison of DSST between digital version and traditional written version [1].

Table 1. Demographic summary by study

Statistic	In-person iPad	Remote smartphone
N	198	146
Age mean (SD)	49 (17)	40 (16)
Age range	19 - 79	19 – 73
Female N (%)	96 (48%)	70 (48%)
Male N (%)	102 (52%)	76 (52%)

Figure 1. Distribution of age from iPad and smartphone data, with age of 40 shown as dashed lines.

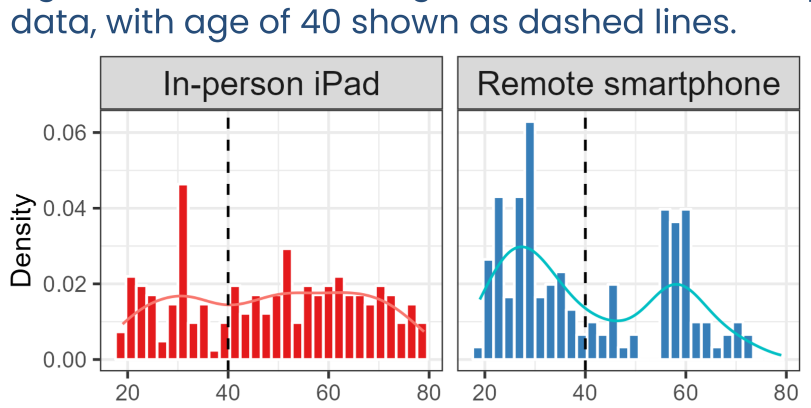


Table 2. Demographic subgroup sample size by study

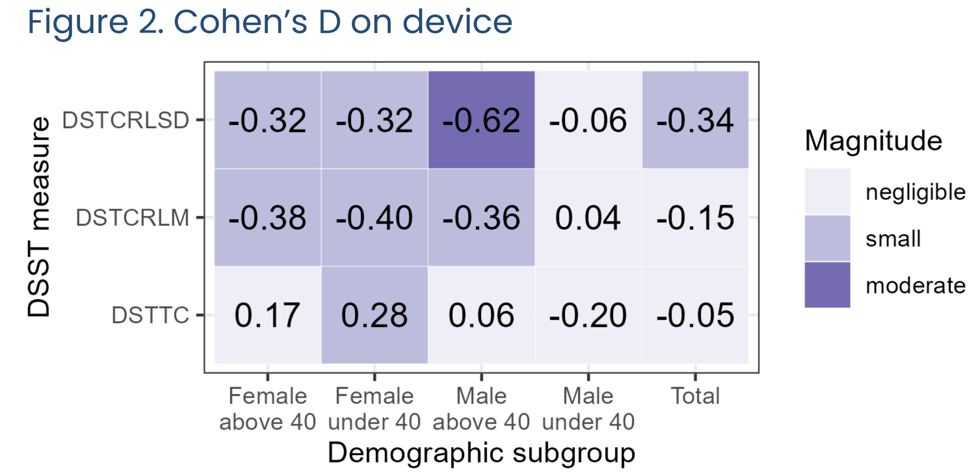
Subgroup N	In-person iPad	Remote smartphone
Female above 40	61	34
Female under 40	35	36
Male above 40	68	29
Male under 40	34	47

Method

Data:
Two groups of participants aged 18-80 with approximately equal number of males and females completed DSST in two studies using either smartphone or iPad devices. Age and gender summaries by study are presented in Table 1. The smartphone data was collected in a remote and unsupervised setting which allows participants to bring their own device (BYOD) for DSST assessment. The iPad data was collected in-person in a controlled environment, with a rater present, with the same iPad and iOS versions used for all DSST administrations. In this analysis, device difference refers to variations primarily driven by the use of different devices, which inherently affect how data collection is administered.

Key Variables:
In addition to the main DSST measure, total correct patterns completed (DSTTC), we additionally examined mean (DSTCRLM) and standard deviation (DSTCRLSD) of reaction time in millisecond (ms) for successfully completing the patterns based on the digital test.

Figure 2. Cohen's D on device



Difference is compared as smartphone data – iPad data.

Table 3. ANCOVA F test results for DSST measures

Outcome Variable	Effect	DF	F Value	P Value
DSTTC (DSST Total Correct)	Gender	1	114.99	0.194
	Age	1	4326.71	**<0.001**
	Device	1	139.27	0.153
	Age × Device	1	9.59	0.708
DSTCRLM (DSST Correct Response Latency Mean)	Gender	1	3.66	0.057
	Age	1	40.98	**<0.001**
	Device	1	9.35	**0.002**
	Age × Device	1	0.04	0.850
DSTCRLSD (DSST Correct Response Latency Standard Deviation)	Gender	1	0.001	0.971
	Age	1	3.12	0.078
	Device	1	8.65	**0.003**
	Age × Device	1	0.004	0.947

Age × Device: Interaction effect between age and device; Significant F test p values (<0.05) are noted in bold font.

Analyses:
To minimize confounding effects from age and gender and understand magnitude of difference, we first examined device difference in DSST measures using Cohen's D effect sizes in four demographic subgroups and overall data. Demographic subgroups were decided due to the bi-modal distribution of age from smartphone data (Figure 1), with enough subgroup size for effect size calculation (Table 2).

We then tested device difference in each measure in overall data using ANCOVA analysis adjusting for age and gender, focusing on 2 aspects:

1) Test on main effect of device for systematic device difference.
2) Test on age and device interaction effect for age slope difference by device, because aging is expected to impact DSST performance.

Figure 3. Least square mean estimates by device

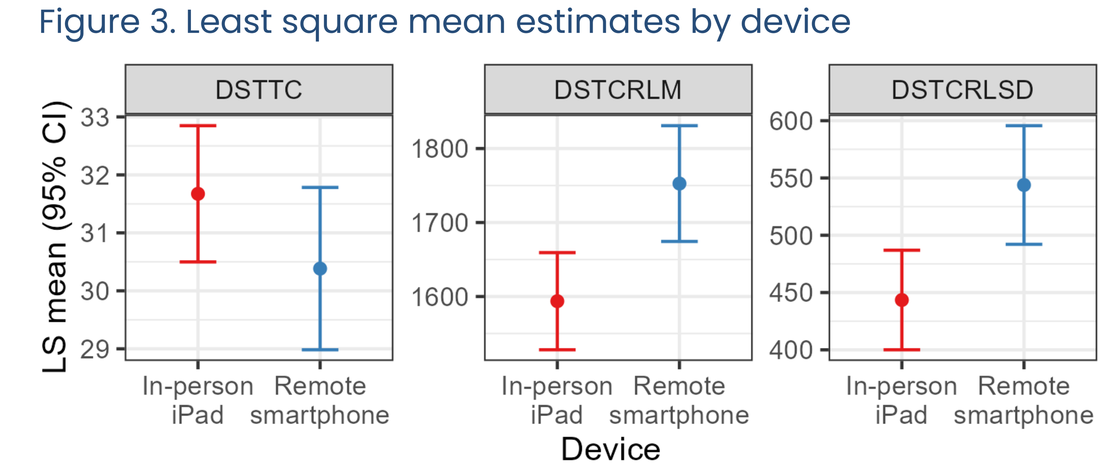
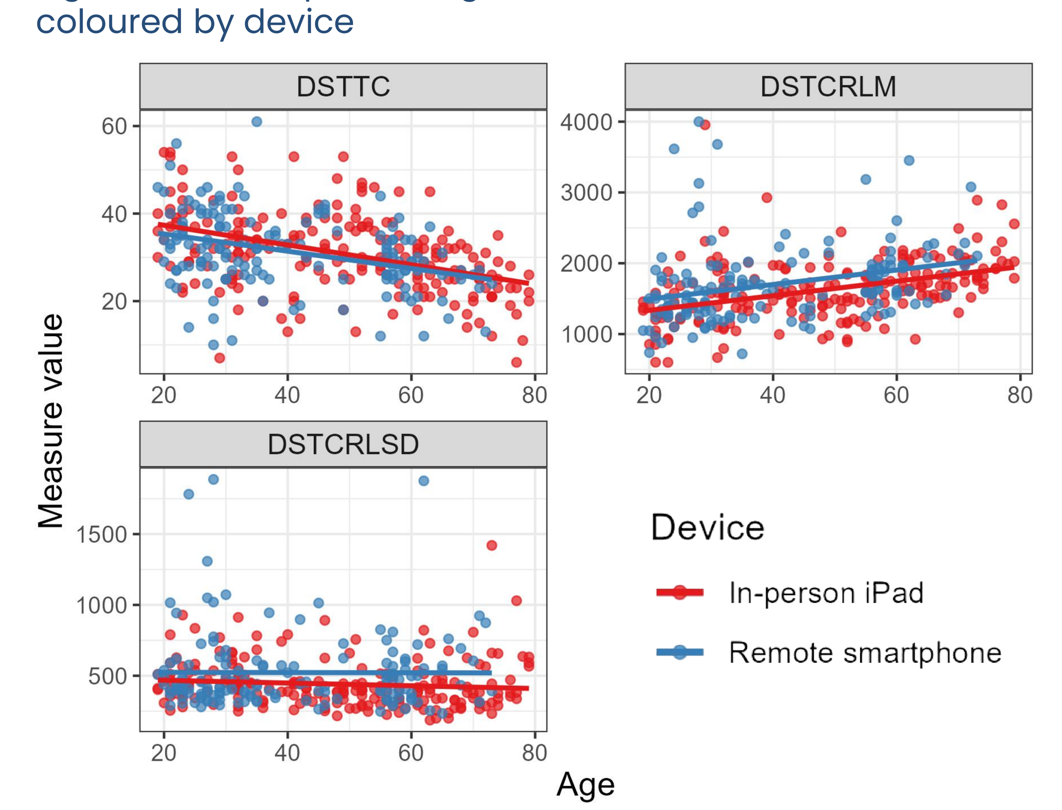


Figure 4. Scatterplots of age vs DSST measures with fitted lines, coloured by device



Results

Among the 3 DSST measures, DSTTC mostly showed negligible differences (|Cohen's D| < 0.2) and DSTCRLM mostly small differences (|Cohen's D| < 0.5) by device. DSTCRLSD showed the same patterns as DSTCRLM in all but one subgroup, where there was a moderate difference in males above 40 with Cohen' D = −0.62 (Figure 2).

In ANCOVA tests on device difference from combined data, there was no significant difference in DSTTC. However, the differences were significant for DSTCRLM ($p = 0.002$) and DSTCRLSD ($p = 0.003$) (Table 3). The least square mean estimate plot shows about 150 ms difference in DSTCRLM and 100 ms difference in DSTCRLSD (Figure 3) between the two administration approaches.

In ANCOVA tests on age slope difference, there was no significant difference for any DSST measure ($p > 0.05$). This can also be observed in age vs DSST measure scatterplots that the slope of fitted lines are very similar, despite the intercept differences (Figure 4).

Conclusion

In summary of results, the main outcome measure DSTTC has good comparability between the devices studied, despite there being some differences in the more detailed reaction time measures.

These differences are potentially due to the supervised, in-person vs remote administration differences, or due to device hardware latency differences, especially from the uncontrolled BYOD smartphone data.

The associations between age and DSST measures are not impacted by device, indicating consistent measure sensitivity by age across devices.

In conclusion, these results validate comparability of digital DSST for use across devices, though comparisons of reaction time should be made with caution if different devices from in-person or remote assessments are used for test administration.

Disclosures

The authors report no conflicts of interest for this work.

Contact

Mengdan Xu: mengdan.xu@camcog.com

Cambridge Cognition Ltd: Tunbridge Court, Tunbridge Ln, Bottisham, Cambridge, CB25 9TU, UK

References

[1] Allen L, Baker E, Thorp E, Evans M, Thorpe D, Granger K, Cormack F, Barnett J, Cashdollar N. (2021, April 6-9). Validation and comparability of smartphone-based digit symbol substitution task with written version. Poster presentation at 17th ISCTM.