



## Background

Slowed information processing is found in many individuals with Multiple Sclerosis (Costa et al., 2016). Cognitive rehabilitation via at-home digital monitoring and therapeutics, including tablet-, smartphone-, and computer-based games may be beneficial to patients. First, we must correlate these candidate games with gold-standard pen-and-paper evaluations and with other clinical measures, to highlight confounding effects including depression (Patel and Feinstein, 2018) as well as avenues for optimizing their development.

## Objectives

- 1) To compare gold-standard, supervised cognitive batteries with exploratory, unsupervised digital tools.
- 2) To examine and address potential confounding factors including emotional burden, motor or visual impairment, and familiarity with technology, to more accurately capture desired outcome measure(s)

## Methods

50 participants with MS completed the Hospital Anxiety and Depression Scale (HADS) and were assessed with a Neurostatus Expanded Disability Status Scale (EDSS) exam, the standardized level of impairment due to MS.

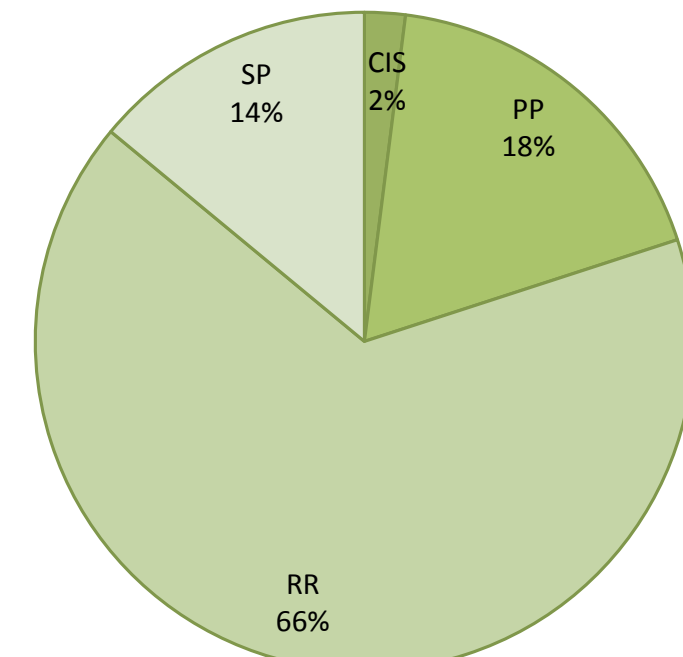
They completed supervised pen-and-paper cognitive tests including Symbol-Digit Modalities Test (SDMT), California Verbal Learning Test (CVLT), and Brief Visuospatial Memory Test (BVMPT).

Next they completed unsupervised tablet- and computer-based tests including a four-part MS Battery and Match, a test of executive function and processing speed developed at UCSF. HADS scores, EDSS, and disease duration were correlated with performance on both supervised and unsupervised cognitive tests.

Table 1: Cohort Characteristics

Variable	Mean (SD)
Age	52.7 (12.5)
Years of Education	16.7 (2.4)
Disease Duration	12.3 (8.9)
EDSS	3.5 (2.0)
SDMT	46.6 (10.8)
HADS - Depression	4.6 (2.9)

Figure 1: Participant Disease Courses



## Results

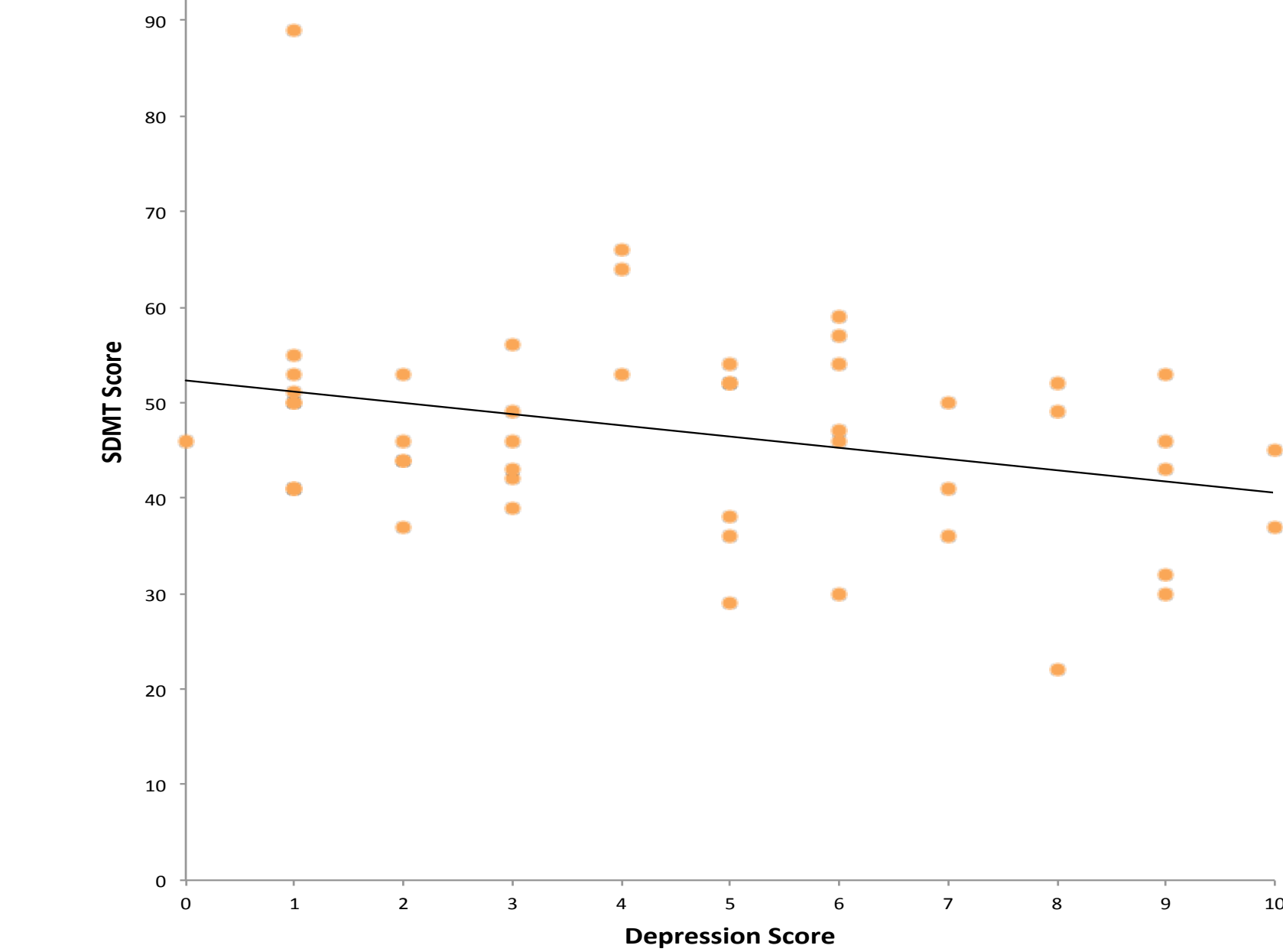


Figure 2A: SDMT performance correlates with depression severity

For these two measures,  $r = -.31$  ( $P = .03$ ). The HADS Depression scale ranges from 0-21 with scores categorized as follows: normal 0-7, mild 8-10, moderate 11-14, and severe 15-21. Our cohort has mild depression overall, suggesting even subtle point differences contribute to the observed effect.

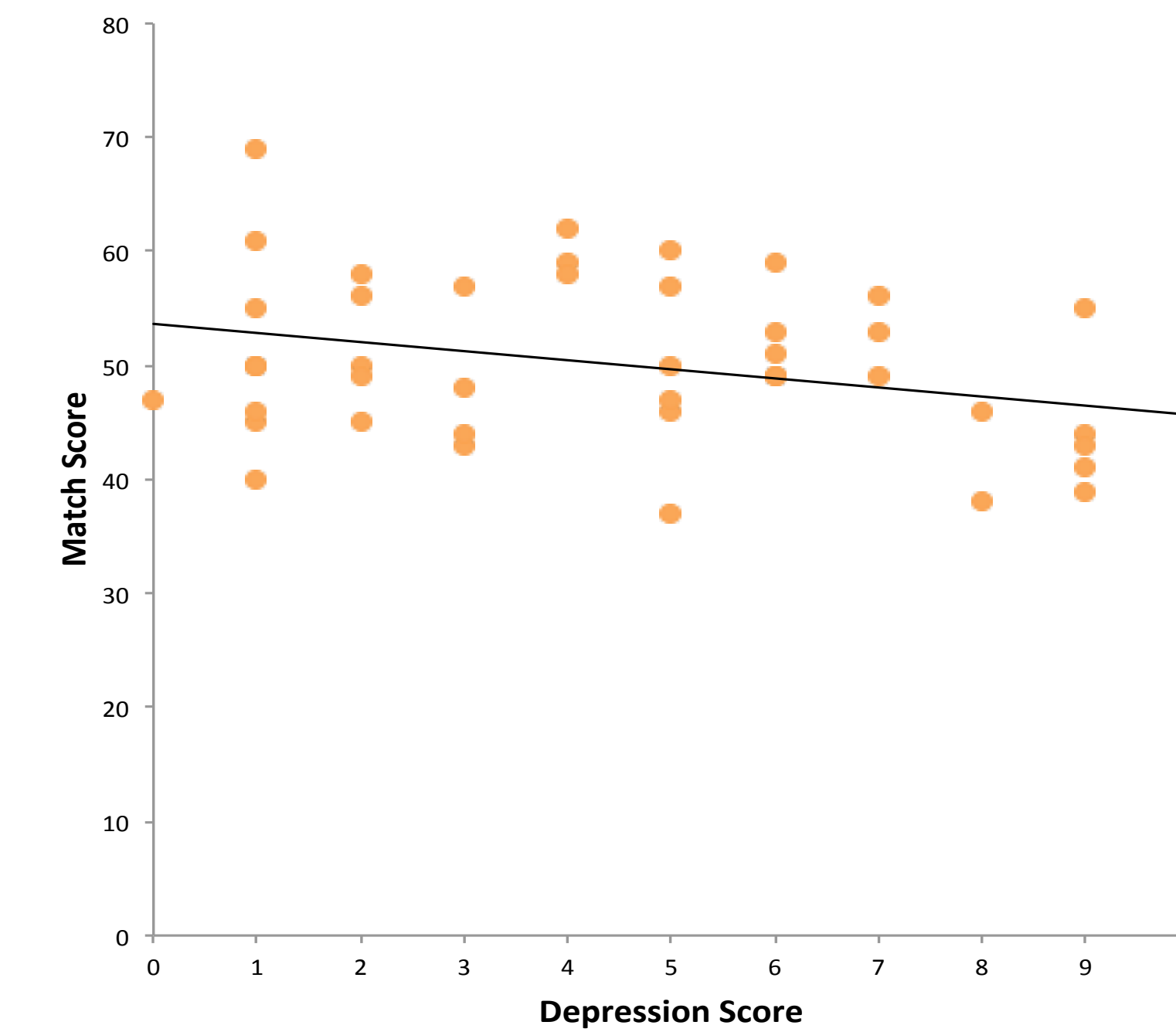


Figure 2B: Match performance correlates with depression severity

Match, an unsupervised, strong correlate of SDMT ( $r = 0.70$ ,  $P < .00001$ ), was also significantly negatively correlated with depression ( $r = -.32$ ,  $P = .03$ ).

## Results Cont.

Depression and anxiety were highly correlated intraindividually (Pearson  $r = .60$ ,  $P < .00001$ ).

The visual learning portion of the computer-based cognitive battery was also significantly impacted by depression ( $r = -.074$ ,  $P = .02$ ).

Disease duration, EDSS, and anxiety did not predict performance on processing speed ( $P > .05$  for each), suggesting depression as a distinct process contributing to these deficits.

## Conclusions

Both supervised (SDMT) and unsupervised (Match) tests of processing speed are significantly impacted by depression. Tests of downstream cognitive processes, including visual memory in this instance, may be affected as well. The HADS can efficiently be administered in parallel with cognitive batteries on the same platforms (computer, tablet, smartphone) to assess patients' emotional burden. As digital cognitive evaluative tools are developed and implemented for at-home training and remote monitoring, depression scores must be captured and accounted for when analyzing cognitive performance outcomes.

## Acknowledgements

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## References

- Patel, V. P., & Feinstein, A. (2018). The link between depression and performance on the Symbol Digit Modalities Test: Mechanisms and clinical significance. *Multiple Sclerosis Journal*, DOI: 1352458518770086.
- Costa, S. L., Genova, H. M., DeLuca, J., & Chiaravalloti, N. D. (2017). Information processing speed in multiple sclerosis: Past, present, and future. *Multiple Sclerosis Journal*, 23(6), 772-789.

## Instruments

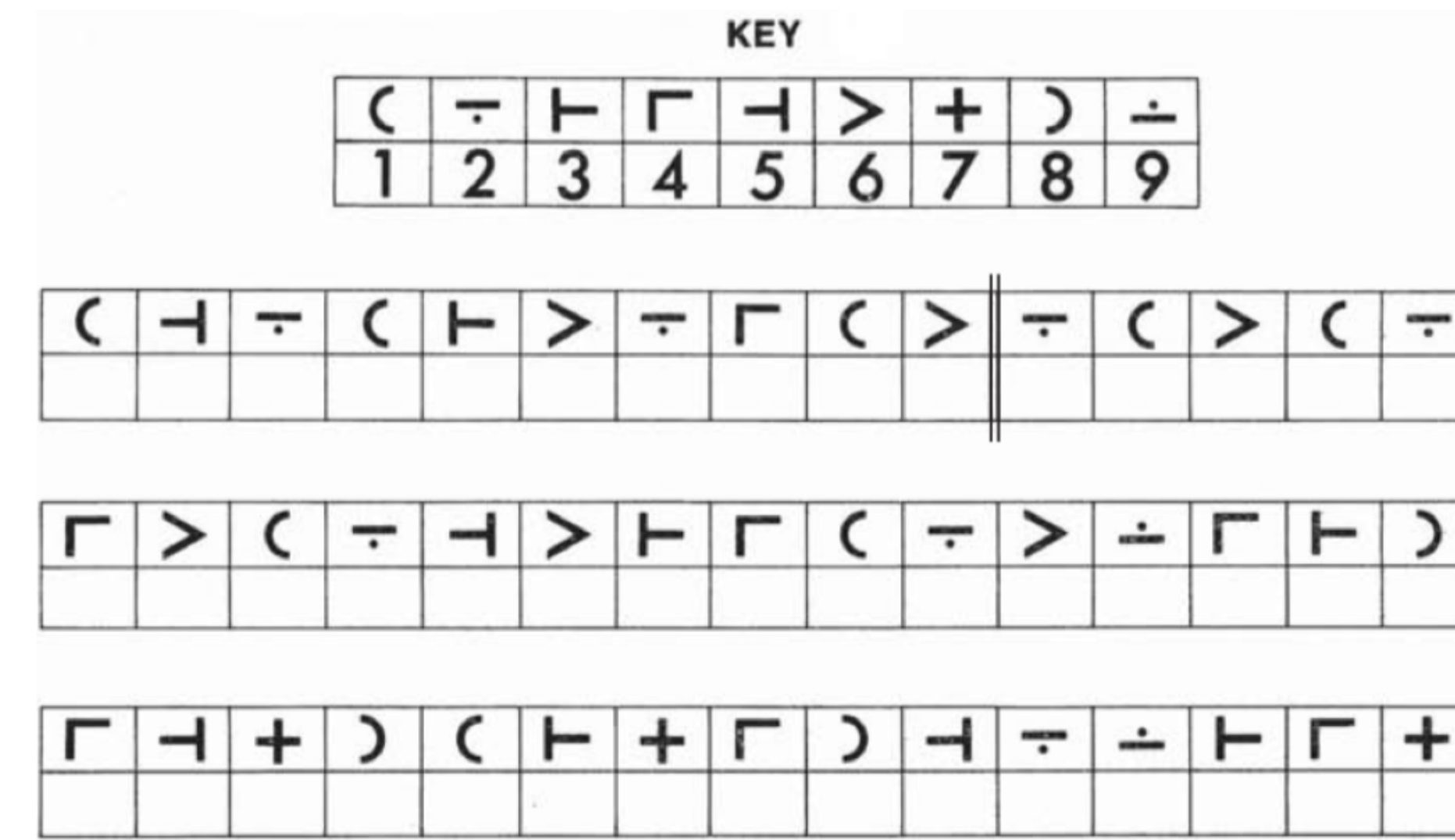


Figure 3A: SDMT

The Symbol Digit Modalities Test is a thoroughly studied, sensitive assessment for cognitive impairment. Participants have 90 seconds to complete as many boxes as possible. If they are unable to write, they may give their answers verbally.



Figure 3B: Match

Developed at UCSF, Match is a tablet-based assessment of processing speed and associative memory. It is modeled after the WAIS-III Digit Symbol Coding paradigm. After a response, a new number is shown. Correct responses after 2 minutes are totaled.