Intact Implicit Sequence Learning in Individuals with Autism

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Background

Individuals with autism have demonstrated impaired performance in nearly all cognitive domains, including learning and memory.

The sequential reaction time (SRT) task, originally introduced by Nissen & Bullmer (1987), has been used to demonstrate procedural acquisition of a visual sequence, reflecting nondeclarative or implicit learning mechanisms.

Mostofsky et al. (2000) demonstrated that individuals with autism were impaired at learning a 10-trial repeating visual sequence using a variant of the SRT task. They argue that abnormalities of the cerebellum in autism prevent acquisition of procedural knowledge on the SRT task.

Is cerebellar or other brain damage actually preventing the acquisition of procedural learning, or is the learning merely slower and requires more training than normal? With additional training, would individuals with autism be able to acquire a visual sequence, or are the underlying mechanisms simply too impaired?

Participants

Table of Participants with Autism

Init	Exp	Age	Diagnostic Tests	IQ Tests
CH	4,8	13	Aberrant Behavior Checklist; Autism Symptom Inventory	WISC III FSIQ: 78
RE	4,8	13	CARS	WISC III FSIQ: 44
NN	4,8	14	Vineland	NA
LN	4,8	11	Vineland, CARS	Four subtests of Leiter-R: 54
RH	8	13	Vineland	CIIS: 12-20 mos
SE	8	6	Vineland, CARS	UNIT Full Scale Raw Score: 108 (average to high average range)
HR	8	6	CARS	NA
EY	4	12	CARS	C-TONI IQ: low-average range

Init: initials; Exp: participation in 8-sequence or 4-sequence experiment; Age: years at time of testing; Diagnostic tests: CARS (Childhood Autism Rating Scale), Vineland Adaptive Behavior Profiles; IQ Tests: WISC III (Wisconsin Intelligence Scale Children III; FSIQ: full scale IQ), Leiter International Performance Scale - Revised, CIIS:Cattell Infant Intelligence Scale; UNIT: Universal Nonverbal Intelligence Test, C-TONI: Comprehensive Test of Nonverbal Intelligence; NA: not available.

4-length Sequence Experiment:

- Autism Group: N = 5; Mean Age: 12.6 years; All males
- Control Group: N = 5; Mean Age: 12.8 years; All males

8-length Sequence Experiment:

- Autism Group: N = 7; Mean Age: 10.9 years; All males
- Control Group: N = 9; Mean Age: 12.3 years; All males

Control group matched for age and gender; no history of seizures or learning disabilities; no siblings diagnosed with autism.

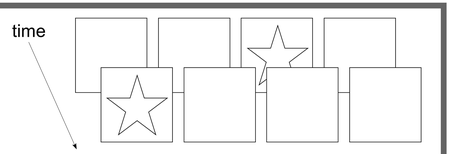
Methods & Design

4-length and 8-length sequences:
12 blocks of 48 trials of a repeated sequence
2 blocks of random probe trials

Autism group = 6 runs through using the same sequence (each separated by 1 week)
Control group = 1 run through each sequence

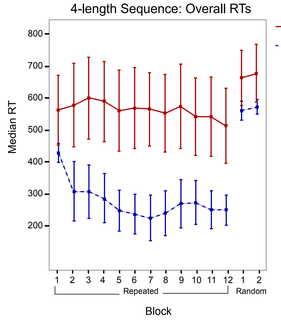
8-length sequence exp run first, followed by 4-length sequence

8-length sequence = each location used twice
4-length sequence = each location used once



- "Touch Star"
- 500 ms ITI
- Reaction time recorded by touch screen
- Star remained on screen until correct response

4-Sequence Results



Each Autistic individual's data from six runs averaged and then averaged for the group. Errors excluded from analyses: 9% Autistic group and 2.4% Control group.

Repeated Measures ANOVA for 12 Repeated Blocks:

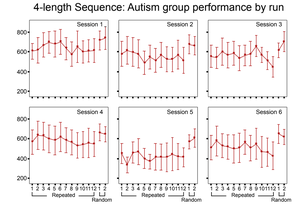
- Autistic group had slower RTs relative to the Control group, $F(1,8) = 4.38$, $p=.07$
- Main effect of Block (RTs decrease from 1st block to the 12th block of repeated trials) $F(11,88) = 2.88$, $p<.01$
- Block x Group Interaction, $F(11,88) = 1.94$, $p<.05$

Rebound Effect Size:
(Difference between last block of Repeated trials and first block of Random trials)

- Control group = 311 msec, $t(4) = -4.74$, $p<.01$
- Autism group = 151 msec, $t(4) = -4.64$, $p<.01$

Final Session for Autistic group:

- Effect Size of 221 msec, $t(4) = -3.81$, $p<.05$



4-length Seq: Overall Effect Size for each autism participant

Participant	Final Repeated Block	First Random Block	Effect Size (Rep – Rand)
RE	246 msec	449 msec	203 msec
LN	718 msec	764 msec	46 msec
CH	608 msec	747 msec	139 msec
NN	576 msec	691 msec	115 msec
EY	250 msec	489 msec	239 msec

The Effect Size for each individual in the Autistic Group was significant, all p's <.05

8-Sequence Results

Each Autistic individual's data from six runs averaged and then averaged for the group. Errors excluded from analyses: 2.7% Autistic group and 2.3% Control group.

Repeated Measures ANOVA for 12 Repeated Blocks:

- Autistic group had slower RTs relative to the Control group, $F(1,14) = 16.86$, $p=.01$
- Main effect of Block (RTs decrease from 1st block to the 12th block of repeated trials) $F(11,154) = 8.32$, $p<.01$
- No Block x Group Interaction

Rebound Effect Size:
(Difference between last block of Repeated trials and first block of Random trials)

- Control group = 50 msec, $t(8) = -1.87$, $p=.10$
- Autism group = 125 msec, $t(6) = -2.25$, $p=.06$

Final Session for Autistic group:

- Effect Size of 126 msec, $t(6) = -2.48$, $p<.05$

8-length Seq: Overall Effect Size for each autism participant

Participant	Final Repeated Block	First Random Block	Effect Size (Rep – Rand)
RE	699 msec	709 msec	10 msec
LN	1170 msec	1212 msec	36 msec
CH	996 msec	1073 msec	77 msec
NN	626 msec	705 msec	79 msec
RH	686 msec	902 msec	216 msec
SE	875 msec	1299 msec	424 msec
HR	582 msec	612 msec	31 msec

No individual in the Autistic Group demonstrated a significant Effect Size.

Conclusions

Individuals with autism demonstrated acquisition of a 4-length sequence, which was significant at an individual level after six study-test runs.

Additional training on an 8-length sequence also resulted in acquisition of the repeated sequence, but only at the group level, with no individual demonstrating robust learning.

Procedural learning in individuals with autism is clearly slower and more variable than in normally developing individuals, but possible with more exposure to the sequence and shorter sequence lengths.

Future research will investigate the role of attention and possible contribution of interference in the performance decrement for the 8-length sequences.

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