

# Impaired linguistic prediction but intact musical prediction in autism spectrum disorder: evidence from Mandarin speakers

Chen Zhao<sup>1</sup> | Allison R. Fogel<sup>2</sup> | Aniruddh D.Patel<sup>2</sup> | Cunmei Jiang<sup>3</sup> | Fang Liu<sup>1</sup> |  
1. School of Psychology and Clinical Language Sciences, University of Reading, Reading, UK. 2. Department of Psychology, Tufts University, Medford, MA, USA. 3. Music College, Shanghai Normal University, Shanghai, China

## Introduction

Individuals with autism spectrum disorder (ASD) have been associated with impaired prediction, which affects the adaptation to the changing world[1]. However, it is unclear whether this deficit is domain-general or -specific. Language and music provide an excellent way to investigate prediction, as both domains involve structured temporal sequences in which expectations are based on implicit learning of combinatorial principles[2]. The present study aimed to examine prediction in music and language in Mandarin speakers with and without ASD with cloze tasks.

## Method

### Participants

Table 1 Demographical characteristics of the sample

	ASD N=31 Mean (SD)	TD N=33 Mean (SD)	Mann-Whitney U	p
Age (years) range	13.17 (4.64) 7.14 – 26.46	12.15 (3.81) 7.55 – 26.88	451.00	0.416
Sex	F = 5, M = 26	F = 5, M = 28	506.50	0.915
Music Training (years)	1.84 (2.98)	0.32 (0.85)	358.00	0.009
NVIQ	37.45 (12.59)	47.30 (6.34)	278.00	0.002
VIQ	112.47 (31.10)	150.30 (13.32)	138.00	<0.001
Digit Span	7.81 (1.25)	8.12 (1.08)	433.50	0.271
Memory	2.95 (1.25)	5.14 (1.15)	96.50	<0.001

Note: F = female, M = male. NVIQ: raw score of Raven Standard Progressive Matrices, VIQ: raw score of The Peabody Picture Vocabulary Test, Memory: Corsi short-term memory test

### Melodic and Sentence Cloze tasks

Participants were asked to produce the final note/word after hearing an unfinished melody/sentence within a 5-sec recording window. In the Melodic Cloze task, participants listened to melodic stems created and validated by Fogel et al. (2015). In the Sentence Cloze task, participants listened to sentence stems that were validated and matched individually with the melodic stems on the length ( $\pm 2$ , i.e. the number of syllables/notes in a stem) and probabilities ( $\pm 3\%$ , the cloze response probability).

Participants’ production was analysed offline. The fundamental frequency of the sung note was matched to the closest semitone ( $\pm 50$  cents) in the Western chromatic scale (e.g., A4 = 440 Hz). Sung notes and spoken word/phrases were compared with the norms and categorised into four categories:

1. No response
2. A response that has not been reported in the norms
3. A less frequent response
4. The most frequent response from the norms

#### Melodic Cloze Task



#### Sentence Cloze Task



Figure 1 An example of cloze tasks.

Table 2 Melodic and sentence stems

Melodic stem			
Range	Mean	SD	
Probability (%)	55.37	21.32	
Length	8.40	0.83	
Pitch (st)	11.4 (mean range)	3.2	
Duration (s)	5.02	1.23	
Sentence stem			
Range	Mean	SD	
Probability (%)	55.78	21.59	
Length	8.36	0.87	
Pitch (st)	13.47 (mean range)	6.43	
Duration (s)	2.54	0.29	

## Results and discussion

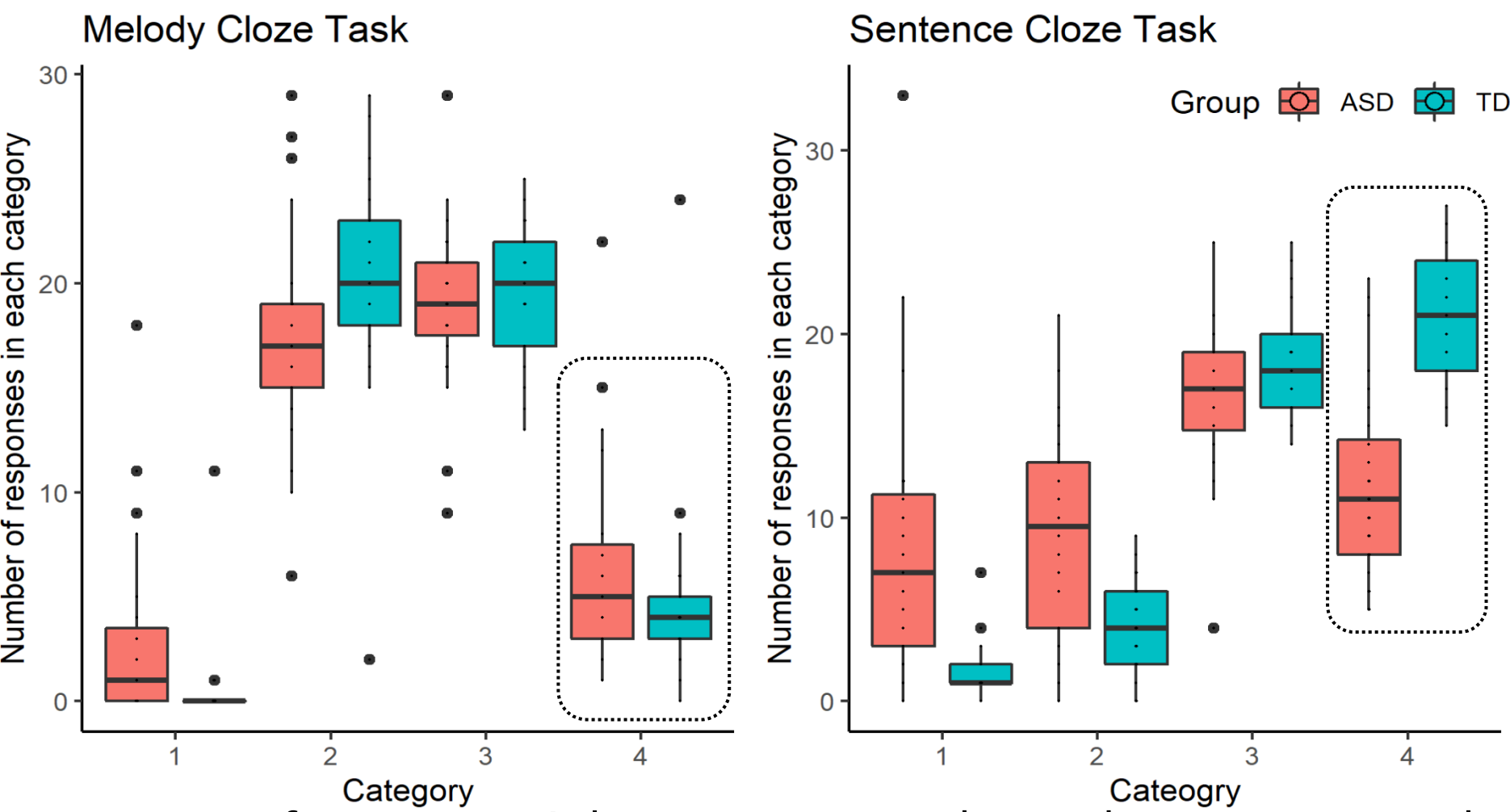


Figure 2 Summary of participants’ cloze responses within each category per task

Table 3 Predictors for the most frequent cloze responses.

Combined Cloze Tasks			
Predictor	Estimate (SE)	z	p
Intercept	-1.28(.12)	-10.54	<.0001
Group	1.11(.13)	8.24	<.0001
Task	-.80(.11)	-7.22	<.0001
Probability	3.28(.47)	7.05	<.0001
Group*Task	-1.43(.15)	-9.24	<.0001
Group*Probability	.91(.45)	2.01	.044
Task*Probability	-2.43(.52)	-4.68	<.0001
Group*Task*Probability	-1.59(.73)	-2.18	.029

Melodic Cloze Task			
Predictor	Estimate (SE)	z	p
Intercept	-2.15(.57)	-3.79	.0002
Group	-.38(.29)	-1.34	.180
Probability	1.03(.41)	2.52	.012
Pitch Match	-.002(.001)	-2.74	.006
Training	-.01 (.04)	-.12	.905
NVIQ	.02(.01)	1.63	.104
VIQ	-.00(.01)	-.06	.954
Memory	-.07(.10)	-.68	.494
Group*Probability	-.81(.58)	-1.40	.161

Sentence Cloze Task			
Predictor	Estimate (SE)	z	p
Intercept	-3.57(.37)	-9.68	<.0001
Group	.87(.17)	5.29	<.0001
Probability	3.68(.65)	5.67	<.0001
Training	.02(.03)	.70	0.483
NVIQ	.01(.01)	1.91	.056
VIQ	.02(.003)	5.28	<.0001
Memory	-.16(.06)	-2.81	.005
Group*Probability	1.01(.49)	2.07	.039

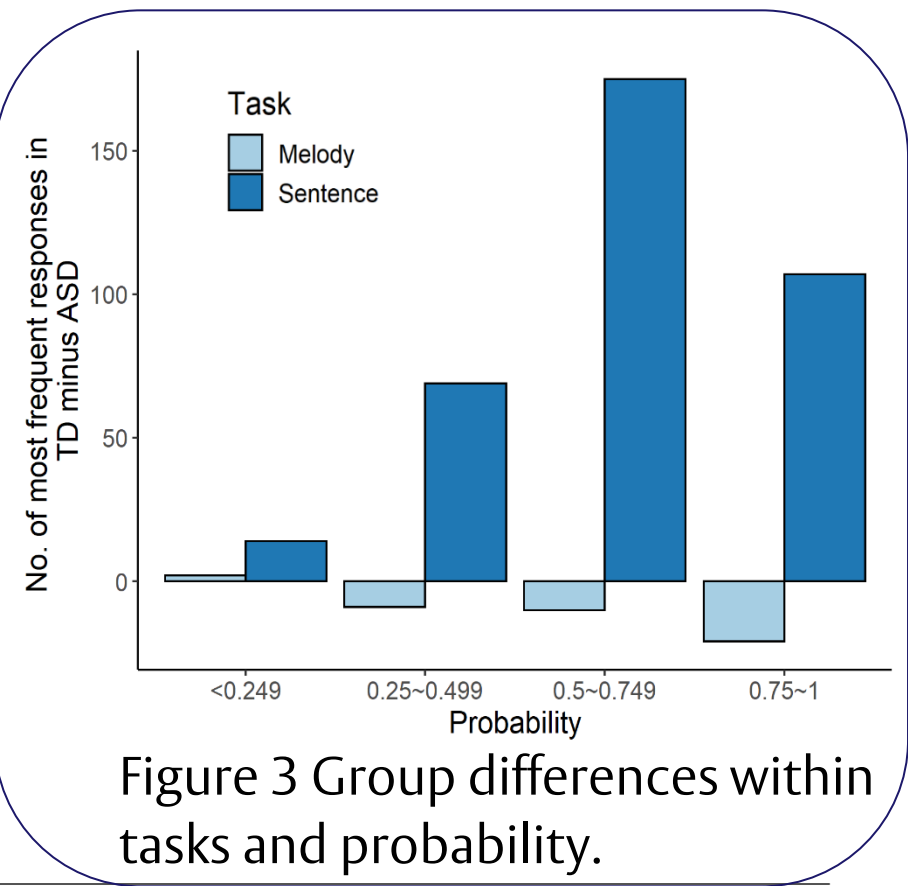


Figure 3 Group differences within tasks and probability.

### Summary of results:

- There was no group difference in the production of the most frequent notes in the Melodic Cloze task (Fig 2).
- ASD group produced significantly less frequent words than the TD group in the Sentence Cloze task (Fig 2).
- Probability positively predicted both groups’ most frequent responses, higher probability generated a greater difference between groups than the lower probability (Fig 3).

In conclusion, findings suggested that both ASD and TD groups show expectations in music and sentence completion tasks. The impairment in linguistic prediction in ASD may not be due to generalised problems with prediction in any type of complex sequence processing.

### References

1. Sinha, P., et al. (2014). Autism as a disorder of prediction. PNAS, 111(42), 15220-15225.
2. Fogel, A. R., et al. (2015). Studying Musical and Linguistic Prediction in Comparable Ways: The Melodic Cloze Probability Method. Frontiers in Psychology, 6.
3. Morgan, E., et al. (2019). Statistical learning and Gestalt-like principles predict melodic expectations. Cognition, 189, 23–34.

### Acknowledgements

- This study was supported by a European Research Council (ERC) Starting Grant, ERC-StG-2015, CAASD, 678733, to F.L. and C.J.
- We thank all the families who participated in our study, and the Master students from Nanchang University who helped with data collection.