Cloze Probability in Visual and Linguistic Narrative Comprehension in Individuals with Autism

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BACKGROUND

Role of Prediction in Semantic Processing

- Language comprehension is facilitated by the prediction of upcoming words in a sentence or narrative [1].
- In the language domain, cloze probabilities are estimates of the expectancy of a target word, such that words that are "high-cloze" are more predictable given the context of the preceding sentence or narrative than words that are "low-cloze" [2].
- Studies using event-related potentials (ERPs) in typically-developing (TD) populations reveal that high cloze words produce reduced amplitudes at the N400 ERP component compared to low words, reflecting facilitated semantic processing (i.e., understanding the meaning of a stimulus).
- In the visual domain, events within a visual narrative sequence can also be classified as "high cloze" or "low cloze" based on the predictability of an event. Recent work from our group shows that cloze modulates N400 amplitude in visual narratives in similar ways as in linguistic narratives [3].

ASD, Semantic Processing, and Narrative Comprehension

- Difficulty with narrative comprehension, across linguistic and non-linguistic modalities [4], is common in autism spectrum disorder (ASD) [5].
- These difficulties suggest domain-general differences in semantic processing and consequentially narrative comprehension.
- ASD has been classified as a "disorder of prediction" [6], so difficulties with predictive processes could contribute to difficulties with narrative processing across modalities.

Here, we use a cloze probability paradigm to explore predictive processing during narrative comprehension in individuals with ASD.

METHODS

Stimuli and Procedure

- Participants viewed visual narrative sequences (*Peanuts* comic strips) for the visual study (Figure 1a) and linguistic narrative sequences for the linguistic study (Figure 1b) one panel/word at a time during concurrent EEG recording.
- ERPs were time-locked to a "target" word or panel of a sentence or comic which was either highly predictable ("high cloze") or unpredictable ("low cloze"), as quantified with a pretest.
- In "anomalous" conditions the target panel or word was incongruent with the preceding narrative. Although we include this condition in the stimuli examples and results, here we focus on the differences in cloze categories.

Participants

- Linguistic study: 21 TD adults (*M* age = 25.5), 21 adults with ASD (*M* age = 33.4) who also completed measures of autistic traits (AQ; [7]) and sentence comprehension abilities (WRAT-5; [8]).
- Visual study: 22 TD adults (*M* age = 25.4), 22 adults with ASD (*M* age = 27.7) who also completed measures of autistic traits (AQ) and visual language fluency (VLFI; [9]).

EEG Data Acquisition, Preprocessing, and Analysis

- EEG data recorded at 500 Hz using a 128-channel Geodesics Sensor net and NetStation 5.3.
- Data bandpass filtered from 0.1-50 Hz and segmented into epochs time-locked to the onset of the target panel or word.

Figure 1: a) Visual stimuli consisted of *Peanuts* comic strips for each condition (high cloze, low cloze, anomalous). Target panels are bolded. b) Linguistic stimuli consisted of 2-sentence narratives for each condition (high cloze, low cloze, anomalous). Target words are bolded.

a)

b) **High cloze**:
Sheila has started a garden out back. More than anything she loves the taste of home-made sauce. She decided to start growing her own **tomatoes**.

Low cloze:
So far, the family had been enjoying the trip. Before this, they had never travelled so far from home. The lucky family even got to see a **zebra**.

Anomalous:
Theo was making preparations for a pie. This was going to be his favorite with **cranes** and whipped cream.

RESULTS

- Repeated-measures ANOVAs in 100 ms time windows from 200-1000 ms for the visual narratives and 200-600 ms for the linguistic narratives with factors of *group* (TD/ASD), *condition* (anomalous/low cloze/high cloze), *site* (frontal/central/parietal), and *laterality* (left/midline/right).
- Individual differences investigated by removing factor of *group* and including level of autistic traits (AQ score), sentence comprehension abilities (WRAT sentence comprehension scores), and visual language fluency (VLFI scores) as continuous variables.

VISUAL DOMAIN

- ***TD group***: Significant modulation by cloze (**low < high**) from 500-600 ms at frontal/central sites (all *p*'s<0.05) and 800-1000 ms in the right hemisphere (all *p*'s<0.05).
- ***ASD group***: Significant modulation by cloze (**high < low**) from 300-400 ms at frontal sites (all *p*'s<0.01).
- ***Group comparison***: No group differences in any time window.
- ***Individual differences:*** Significant interactions between AQ and low-high cloze difference waves from 500-600 ms and 800-1000 ms (all *p*'s<0.1).

Figure 2: The ERPs at the critical panel of the visual narratives in each condition for the TD & ASD group at a frontal cluster. Negativity is plotted upwards.

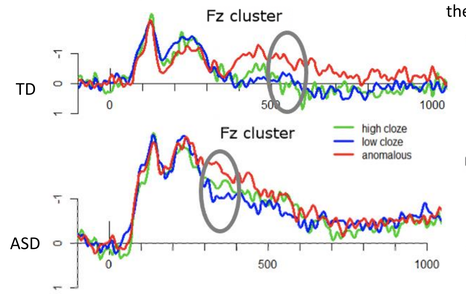


Figure 3: a) Low-high cloze difference waves of the ERPs at the critical panel for each group. b) Topographic plots of the difference waves (low cloze – high cloze) in each group for the visual narratives across the time windows of interest.

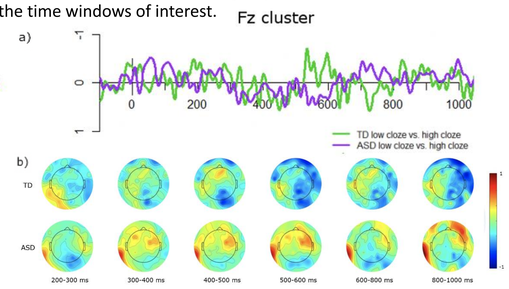
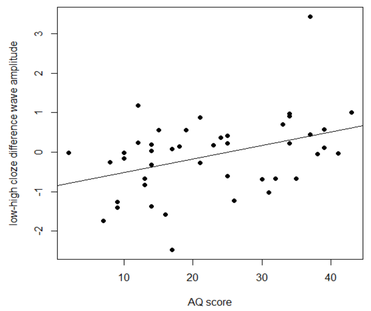


Figure 4: Interaction between WRAT and low-high difference waves from 200-300 ms.



LINGUISTIC DOMAIN

- ***TD group***: Significant modulation by cloze (**low < high**) from 400-500 ms (all *p*'s<0.01) in right/midline sites and from 500-600 ms in central sites (all *p*'s<0.01).
- ***ASD group***: Significant modulation by cloze (**low < high**) from 200-400 ms (all *p*'s<0.001) across all sites.
- ***Group comparison***: No group differences in any time window.
- ***Individual differences :*** Significant positive correlation between WRAT score and low-high cloze difference wave amplitude (r = 0.37, p < 0.05) from 200-300 ms in left central sites.

Figure 5: The ERPs at the critical panel of the linguistic narratives in each condition for the TD & ASD group at a central site. Negativity is plotted upwards.

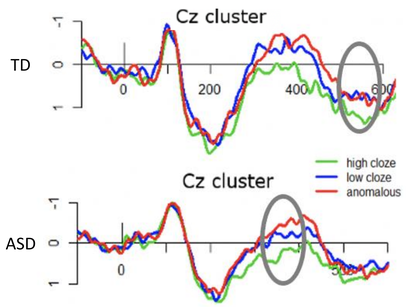


Figure 6: a) Low-high cloze difference waves of the ERPs at the critical panel for each group. b) Topographic plots of the difference waves (low cloze – high cloze) in each group for the linguistic narratives across the time windows of interest.

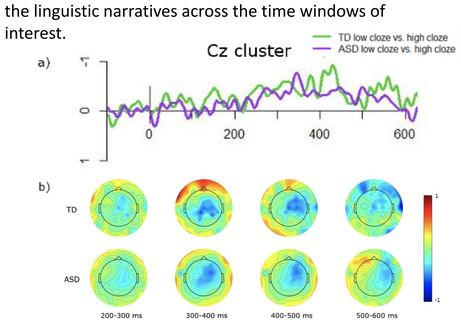
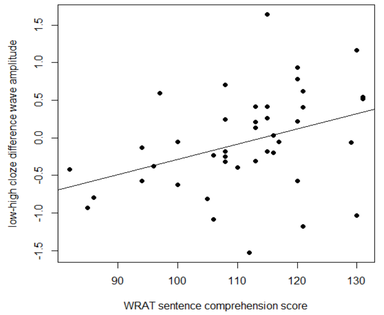


Figure 7: Interaction between WRAT and low-high difference waves from 200-300 ms at left central sites.



CONCLUSIONS

- TD individuals showed larger negative amplitudes for low cloze compared to high cloze stimuli in both modalities, replicating previous findings that unpredictable stimuli are harder to integrate than more predictable stimuli.
- Individuals with ASD showed *earlier* negative amplitudes for both linguistic and visual domains yet had flipped effects of cloze (high cloze > low cloze) that were related to higher autistic trait levels (AQ scores).
- Earlier processing in the ASD group may be a result of a bottom-up processing style in individuals with ASD versus a top-down processing in TD individuals. Active, top-down predictive mechanisms mean that unmet predictions must be overcome, and unpredicted stimuli integrated with existing stimuli, which shifts processing later. More bottom-up processing without active prediction means that processing goes straight to semantic access, resulting in earlier effects.
- These results also revealed associations between factors like autistic traits, visual fluency, and sentence comprehension abilities that may play a role in the influence that cloze has on semantic processing.

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