Project Proposal (v.3)

Title: The Taste of Regulation: Exploring Oral Sensitivity, Eating Behavior, and Parental Well-Being in Autism

Introduction: Children with autism spectrum disorder (ASD) frequently exhibit heightened oral sensory sensitivity, which can make every-day experiences like eating overwhelming or aversive (Nimbley, Golds, Sharpe, Gillespie-Smith, & Duffy, 2022; Zickgraf, Richard, Zucker, & Wallace, 2022). These sensitivities often manifest as selective eating behaviors, i.e., refusing food based on taste, texture, or smell. Importantly, oral sensory atypicalities are not confined to feeding challenges, as they have also been linked to broader difficulties in emotion regulation and behavior problems, suggesting a shared regulatory vulnerability (Sung, Lin, Chu, & Lin, 2024). Supporting this connection, neuroimaging studies in typical adults have identified gustatory-interoceptive integration in the mid-insula, a region also implicated in emotional processing (Avery et al., 2017).

While some research has found associations between selective eating and internalizing symptoms in autistic samples, findings have been mixed (Johnson et al., 2014; Page, Souders, Kral, Chao, & Pinto-Martin, 2022; Tanner et al., 2015). This inconsistency may stem from the need for integrative models that consider additional factors beyond the child-level.

Importantly, these child-level challenges unfold within family systems, where parental mental health plays a critical role. Parents of children with ASD often report elevated stress around mealtimes, which can become emotionally charged routines due to feeding difficulties (Crowe, Freeze, Provost, King, & Sanders, 2016). Moreover, parental emotional responses and feeding strategies are strong predictors of children's eating behavior, potentially reinforcing or buffering selective patterns (Zlomke, Rossetti, Murphy, Mallicoat, & Swingle, 2020). Thus, child sensory sensitivities and caregiver mental health may interact to influence outcomes.

Few studies have integrated these dimensions, i.e., oral sensory sensitivities, eating behaviors, observed emotion regulation, and caregiver factors, into a unified framework. This project addresses this gap by examining how oral sensory sensitivity contributes to emotion dysregulation in autistic children, both directly and indirectly via selective eating, and by testing whether parental mental health amplifies or attenuates these associations. By leveraging large-scale NDA datasets and harmonizing sensory measures through PCA, this study provides a novel systems-level perspective on sensory reactivities in autism.

Aims and Research Questions:

<u>Aim 1:</u> Is oral sensory sensitivity associated with greater emotion dysregulation in autistic children?

- Hypothesis: Higher levels of oral sensory sensitivity will predict greater emotion dysregulation, as measured by the CBCL-Dysregulation Profile.

Aim 2: Does parental mental health moderate the relationship between oral sensory sensitivity and emotion dysregulation?

- Hypothesis: Parental mental health (Adult Behavior Checklist) will moderate the relationship between oral sensitivity and emotion dysregulation, such that the association is stronger when parental mental health challenges are higher.

Aim 3 (Exploratory mechanistic extension): Do selective eating behaviors statistically mediate the link between oral sensitivity and child emotion dysregulation?

- Hypothesis: Higher levels of oral sensory sensitivity will be associated with greater emotion dysregulation, and this association will be partially explained by selective eating behaviors (CEBQ). These analyses are exploratory and hypothesis-generating, as CEBQ is only available in one dataset.
- **NOTE:** While all measures are cross-sectional, mediation is tested based on theoretical precedence, rather than temporal inference. A consistent association between oral sensory sensitivity and selective eating has already been established in the literature (Descrettes-Demey et al., 2023; Elsayed, Thompson, Conklin, & Watson, 2022).

Datasets:

- NDA Study #2021 (https://nda.nih.gov/edit_collection.html?id=2021)
- NDA Study #2804 (https://nda.nih.gov/edit_collection.html?id=2804)
- NDA Study #2828 (https://nda.nih.gov/edit_collection.html?id=2828)
- NDA Study #2834 (https://nda.nih.gov/edit_collection.html?id=2834)
- NDA Study #3005 (https://nda.nih.gov/edit_collection.html?id=3005)

Variables of Interest:

- ASD Diagnosis:
  - Dataset *ndar_subject01*, variable *phenotype*
  - Dataset #2834 did not include dataset *ndar_subject01*, so ASD diagnoses were extracted from variable *scoresumm_adosdiag* within datasets *ados2_201201* and *ados3_201201*
- Sensory:
  - Adolescent/Adult Sensory Profile (AASP): dataset *sens_ad01*
    - Taste/Smell Subscale items *sensory_a_1*, *sensory_a_2*, *sensory_a_3*, *sensory_a_4*, *sensory_a_5*, *sensory_a_6*, *sensory_a_7*, *sensory_a_8*
    - Original scoring: 1 = Almost never; 2 = Seldom; 3 = Occasionally; 4 = Frequently; 5 = Almost always
  - Sensory Profile (SP) Version 1: dataset *sens_car01*

        - Oral Sensory Processing Subscale items *sensory_c_54*, *sensory_c_55*, *sensory_c_56*, *sensory_c_57*, *sensory_c_58*, *sensory_c_59*, *sensory_c_60*, *sensory_c_61*, *sensory_c_62*, *sensory_c_63*, *sensory_c_64*, *sensory_c_65*
        - Original scoring: 1 = Always; 2 = Frequently; 3 = Occasionally; 4 = Seldom; 5 = Never; 999 = NA
            - Only 10 of the 12 oral items were reported for #2834.
    - Sensory Profile (SP) Version 2: dataset *sprcar201*
        - Oral Sensory Processing Subscale items *sensory_c_54*, *sensory_c_55*, *sensory_c_56*, *sensory_c_57*, *sensory_c_58*, *sensory_c_59*, *sensory_c_60*, *sensory_c_61*, *sensory_c_62*, *sensory_c_63*, *sensory_c_64*, *sensory_c_65*
        - Original scoring: 1 = Always; 2 = Frequently; 3 = Occasionally; 4 = Seldom; 5 = Never; 999 = NA
    - Short Sensory Profile (SSP) Version 1: *sps01*
        - Taste/Smell Sensitivity subscale items *sensory_c_55*, *sensory_c_56*, *sensory_c_57*, *sensory_c_58*
        - Original scoring: 1 = Always; 2 = Frequently; 3 = Occasionally; 4 = Seldom; 5 = Never; 999 = NA
    - Short Sensory Profile (SSP) Version 2: *sps2_01*
        - Taste/Smell Sensitivity subscale items *sens_food_rej*, *sens_picky_taste*, *sens_food_text*, *sens_pciky_eat*
        - Original scoring: 0=Does not apply; 1=Almost never; 2=Occasionally; 3=Half the time; 4=Frequently; 5=Almost always
- Emotion Dysregulation:
    - Child Behavior Checklist-Dysregulation Profile (CBCL-DP): dataset *cbcl01*
        - Items for QC: 80% completeness
            - Aggressive Behavior has 18 items: *cbcl3*, *cbcl16*, *cbcl19*, *cbcl20*, *cbcl21*, *cbcl22*, *cbcl23*, *cbcl37*, *cbcl57*, *cbcl68*, *cbcl86*, *cbcl87*, *cbcl88*, *cbcl89*, *cbcl94*, *cbcl95*, *cbcl97*, *cbcl104*
            - Anxious/Depressed has 13 items: *cbcl14*, *cbcl29*, *cbcl30*, *cbcl31*, *cbcl32*, *cbcl33*, *cbcl35*, *cbcl45*, *cbcl50*, *cbcl52*, *cbcl71*, *cbcl91*, *cbcl112*
            - Attention Problems has 10 items: *cbcl1*, *cbcl4*, *cbcl8*, *cbcl10*, *cbcl13*, *cbcl17*, *cbcl41*, *cbcl61*, *cbcl78*, *cbcl80*
            - Study #2828 reported CBCL subscales, but not individual items. QC for 80% completeness could not be completed.
        - Computed t-scores
            - *cbcl_attention*
            - *cbcl_aggressive*
            - *cbcl_anxious*
- Parental Mental Health:

    - Adult Behavior Checklist (ABCL)
- Selective Eating Behavior:
    - Child Eating Behavior Questionnaire (CEBQ)
- Covariates:
    - Age, Race, Sex, ASD severity (measured via the Social Responsiveness Scale, SRS)

Dataset	AASP (*sens*_ad01) Included?	SP Included?	SSP Included?	CBCL (*cbcl01*) Included?	ABCL (*abcl_men_200301*) Included?	CEBQ (*cebq01*) Included?	SRS (*srs201*) Included?
2021	Yes	Yes (*sens_car01*)	No	Yes	No	No	Yes
2804	Yes	No	No	Yes	Yes	Yes	Yes: Raw Scores Only
2828	No	Yes (*sens_car01*)	No	Yes (Only Total Scores)	No	No	Yes: Raw Scores Only
2834	No	Yes (*sprcar201*)	No	Yes	No	No	Yes
3005	Yes	No	No	Yes	Yes	Yes	Yes: Raw Scores Only

Data Analysis Plan:

<u>Dataset Selection</u>

We searched the National Institute of Mental Health Data Archive (NDA) for projects containing both the CBCL and at least one Sensory Profile variant (AASP, SP, or SSP). To ensure relevance, we restricted inclusion to datasets explicitly referencing autism in their respective project descriptions. This yielded ten eligible datasets (#2021, #2026, #2251, #2253, #2281, #2804, #2828, #2834, #2900, #3005), only five of which contained the necessary data upon further inspection in *R* (#2021, #2804, #2828, #2834, #3005).

<u>Participant Exclusion Criteria</u>:
Participants must be coded as “ASD,” “Proband,” or “PA” in demographics (*ndar_subject01*).

Aim-specific inclusion rules:

- **Aim 1 (Sensory Profile → CBCL-DP):** Exclude if missing a variant of the Sensory Profile, the CBCL, or Covariates (Age, Race, Sex, SRS)
- **Aim 2 (Moderation: AASP × ABCL → CBCL-DP):** Exclude if missing a variant of the Sensory Profile, ABCL, CBCL, or covariates (Age, Race, Sex, or SRS)
- **Aim 3 (Exploratory):** Exclude if missing a variant of the Sensory Profile, CEBQ, the CBCL, or covariates (Age, Race, Sex, or SRS)

Scoring and Variable Derivation:

- **Sensory Profiles:**
  - **Eligibility:** Participants will be included only if they have sufficient item coverage: ≥75% observed items for relevant subscale of the SSP (i.e., no more than 1 missing item on the taste/smell subscale) or ≥80% observed items for the AASP (i.e., no more than 1 missing on the taste/smell subscale) and SP (i.e., no more than 2 missing on the oral processing subscale).
  - **Scoring conventions**: For all versions of the Sensory Profile (AASP, SP, SSP), we will use raw item scores. SP-Version 1, SP-Version 2, and SSP-Version 1 items will be reverse-coded so higher values reflect greater sensitivity across all sensory profile questionnaires.
  - **Imputation**: Within eligible cases, we will impute missing values using a decision tree–based method, which has been shown to align closely with original data and outperform alternative imputation approaches with ordinal data (Alam, Ayub, Arora, & Khan, 2023).
  - **Exploratory factor analysis (EFA)**: To identify modality-level groupings, we will conduct an EFA on a polychoric correlation matrix of pooled oral/taste/smell items from the AASP, SP, and SSP following the steps outlined by Loewen and Gonulal (2015):
    - *Factorability:* Report Kaiser-Meyer-Olkin (overall and item-level MSA; target overall ≥ .60); multicollinearity (determinant/eigenvalues/condition number/max inter-item r); Bartlett's test will be documented but not used for decisions given large sample size and estimated polychorics.
    - *Extraction:*
      - Primary: WLSMV to respect missingness and ordinal structure (Kyriazos & Poga-Kyriazou, 2023)
      - Sensitivity: MLR to evaluate model comparability when treating Likert as continuous
    - *Retention:* Factor Forest, with Parallel Analysis on polychorics as a corroborating rule (Goretzko & Bühner, 2022); if they differ by ±1, compare k−1, k, k+1 and select the smallest k with clear simple structure and acceptable residuals
    - *Rotation:*
      - Primary: Oblique direct oblimin with δ=0 (quartimin) (Howard, 2016)
      - Sensitivity: Geomin
    - *Item retention:* Apply the ".40–.30–.20" rule on the pattern matrix (primary ≥ .40; all cross-loadings < .30; gap ≥ .20) and monitor

communalities (prefer $h^2 \geq .20$); retain ≥ 3 solid indicators per factor (Howard, 2016)

- **Instrument effects**: To consider whether instrument format affects results, we will run a multi-group EFA with groups defined by instrument (AASP, SP, SSP) (Sterner, De Roover, & Goretzko, 2025):
    - WLSMV on polychoric correlations; factors are oblique.
    - Number of factors (k) will be fixed across groups to the value previously selected in the pooled EFA (Factor Forest + PA)
    - To align axes across instruments, we will use an oblique target rotation with a partially specified target derived from the pooled oblimin (δ=0) solution (likely zeros set to 0; primaries left free)
    - Configural and approximate metric similarity will be assessed via Tucker's φ of loadings (aim $\varphi \geq .95$, per Lorenzo-Seva and Ten Berge (2006)) and fit indices. CFI/TLI ≥ .90 considered acceptable and ≥ .95 good; RMSEA ≤ .08 acceptable and ≤ .05 good; SRMR ≤ .08 acceptable (Hu & Bentler, 1999). As these cutoffs were developed under ML for continuous data (Xia & Yang, 2019), we will interpret cautiously and, where feasible, use simulation-based dynamic fit indices (McNeish, 2023) as a sensitivity check.
- **Cross-validation**: We will cross-validate by splitting samples by participant (not by instrument).
- **Factor scoring**: After establishing the factor structure, participant-level factor scores will be computed within each dataset. For a given factor, a score will only be assigned if a participant has completed at least 75% of the items contributing to that factor. Otherwise, the factor score will be set to missing.
- **Reporting**: Results will be documented in accordance with Watkins (2018)

- **CBCL-DP:**
    - The CBCL-DP is composed of the summed T-scores from three CBCL subscales: Attention Problems, Aggressive Behavior, and Anxious/ Depressed (Althoff, Ayer, Rettew, & Hudziak, 2010). Although originally developed for neurotypical children, the scale has been validated (Keefer, Singh, Kalb, Mazefsky, & Vasa, 2020) and experimentally implemented in autistic samples (Greenlee, Stelter, Piro-Gambetti, & Hartley, 2021; Vasa et al., 2022). CBCL outcomes will be taken from NDA-provided T-scores, which are ASEBA-normed by age and sex. To align with our completeness rule, T-scores will only be retained when ≥80% of contributing items are observed. For datasets lacking item-level CBCL responses, we will use a T-score validity fallback, retaining participants only when all three DP T-scores are present, within the allowable range (0–100) and not special/missing-coded, and flag these cases as 'T-score–only' for sensitivity analyses.

- **ABCL / CEBQ:** Standard scoring; require ≥80% item completion.

Aim 1: **Linear Regression**
To test whether distinct components of oral sensory sensitivity predict emotion dysregulation in autistic children:

- **Model:** CBCL-DP ~ Sensory Modality + Age + Race + Sex + SRS
    - **Predictors:** PCA-derived modality-specific scores.
    - **Outcome:**
        - Primary Outcome: CBCL-DP
        - Secondary Outcomes: CBCL-DP subscales analyzed separately.
    - **Covariates:** Age, Race, Sex, ASD severity (SRS),
    - To control for multiple comparisons, Benjamini–Hochberg false discovery rate (BH-FDR) correction will be applied within each sensory modality.

Aim 2: **Moderation Analysis**
To test whether parental mental health moderates the association between oral sensitivity and emotion dysregulation:

- **Model:** CBCL-DP ~ Sensory Modality * ABCL + Age + Race + Sex + SRS
- **Probe:** Simple slopes (±1 SD ABCL) with interaction plots for significant interactions.
- **Multiple testing:** BH-FDR within the CBCL-DP.

Aim 3 (Exploratory): **Mediation Analysis**
To examine whether selective eating behaviors statistically mediate the association between oral sensory sensitivity and emotion dysregulation:

- **Models:**
    - CEBQ ~ Sensory Modality + Age + Race + Sex + SRS
    - CBCL-DP ~ Sensory Modality + CEBQ + Age + Race + Sex + SRS
    - Indirect effect via bootstrap (5,000 resamples; bias-corrected 95% CIs).
- Results will be framed as hypothesis-generating due to cross-sectional design.

Expected Contributions:

This project will provide novel insights into oral sensory processing and emotional development in autism, advancing the field in three key ways:

1. **Innovative Measurement:** By harmonizing oral/taste/smell items across multiple sensory measures and applying EFA, this study introduces a data-driven approach that increases comparability across instruments and moves beyond reliance on predefined subscales.
2. **Linking Sensory Traits to Emotional Outcomes:** While most prior work has emphasized feeding behavior, this project positions oral sensitivity as a *regulatory trait*

that contributes directly to emotion dysregulation. This shift broadens how we conceptualize sensory influences on mental health in autism.

3. **Contextualizing Within the Family System:** Testing parental mental health as a moderator highlights how child outcomes are shaped not only by individual traits but also by family-level functioning. This dyadic perspective addresses a gap in models of sensory processing.

4. **Exploratory Mechanistic Pathways:** Mediation analyses (in datasets with CEBQ) provide preliminary evidence for selective eating as one candidate mechanism, setting the stage for confirmatory longitudinal work.

Overall, by combining methodological rigor with a systems-level perspective, this project will be the first to leverage harmonized sensory data across multiple large ASD cohorts to test child and family-level pathways to emotion dysregulation. Findings will inform future interventions that target both sensory sensitivities and caregiver support.

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