

Online Supplementary Information

Many-Dimensional Model of Adolescent School Enjoyment:

A Test Using Machine Learning from Behavioral and Social-Emotional Problems

Supplementary Table S1 Reporting items checklist for assessing machine learning methodology based on Senior et al. (2021) and Christodoulou et al. (2019)

| Reporting item domain | Summary | Manuscript location for further details |
|---------------------------------------|---|--|
| Participants | | |
| Eligibility criteria ¹ | Parent and adolescent informed consent; no other eligibility criteria | Participants section, p. 3 |
| Age range ¹ | 12-18 years; $M = 14.0$ years | Participants section, p. 3 |
| Sample characteristics ¹ | $N = 3232$ of a nationally representative non-clinical, school-based sample from 4 government schools in Singapore; Gender: 49% female, 51% male; Race: 65% Chinese, 23% Malay, 5% Indian, 7% Others | Participants section, p. 3 |
| Predictors | | |
| Predictor details ^{1,2} | Self-reported Likert scale data on 99 items from four instruments: PEQ, BSSS-C, PPI and YSR | Measures section, pp. 3-4 |
| List of all predictors ^{1,2} | 99 item-level predictors from four instruments; same predictors used for development and test sets for all classifier families | Supplementary Table S2 |
| Continuous predictors ^{1,2} | All predictors were ordinal. Implicitly assumed to be continuous for certain classifiers (e.g., linear discriminant analysis). | Measures section, pp. 3-4 |
| Handling of predictors ^{1,2} | All 99 predictor variables used as they were after data collection. No variable selection, no transformation and no special treatment other than hyperparameter optimization in main analysis; Variable selection and transformation were used in additional analysis | Measures section, pp. 3-4; Data and machine learning workflow section, pp. 4-6 |
| Outcomes | | |
| Outcome details ¹ | Self-reported Likert scale data of single-item outcome measure: "How much do you enjoy school and school activities?" | Measures section, p. 3-4 |
| Number of outcome events ¹ | $N = 164$ (25.4%), 419 (64.9%) and 63 (9.8%) cases in the outcome categories of "above average", "average" and "below average" respectively | Data and machine learning workflow section, pp. 4-5 |
| Imbalanced outcome ² | Use of synthetic minority oversampling (SMOTE) in development set | Data and machine learning workflow section, pp. 4-6 |
| Missing data | | |
| Missing data amount ¹ | Less than 0.2% missing for predictor and outcome variables | Measures section, pp. 3-4 |
| Handling of missing data ¹ | Imputed for each set independently (development and test sets) using K nearest neighbor | Measures section, pp. 3-4 |
| Model overfitting | | |

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|--|--|---|
| Validation ^{1,2} | 80:20 single random split for development and test set; 5-fold cross validation for model development set | Data and machine learning workflow section, p. 5 |
| Events per predictor variable (EPV) ¹ | EPV is typically defined for models predicting binary outcomes. Here, we used multi-class (3 outcomes) prediction. Nonetheless, focusing on the combined events for two minority outcome categories of “below average” and “above average” for development set was 11.5 events per predictor variable for the main item-level analysis and 126.3 for the construct-level analysis | |
| Modeling methods | | |
| Modeling steps ^{1,2} | 80:20 split for development and test sets. Development involved minority oversampling, Bayesian hyperparameter optimization and 5-fold cross-validation of 4 families of classifiers (logistic regression, linear discriminant analysis, artificial neural network, and K nearest neighbor). Best cross-validated model for each classifier family in development set then used to predict outcomes in test set. | Data and machine learning workflow section, pp. 4-6 |
| Model performance ² | Performance in test set reported via MCC | Figures 1, 2 |
| Reliability of risk ^{1,2} | Not assessed | |
| Statistical power ¹ | For test set, smallest event number is 227 (combined minority outcome categories of “below average” and “above average”) | Data and machine learning workflow section, p. 4 |
| Replication | | |
| Full model ¹ | The full machine models are available upon request as Matlab objects. | Model explainability section, p. 6 |
| Use of model ¹ | The full machine models are available upon request as Matlab objects. | Model explainability section, p. 6 |
| Simplified score ¹ | Probability outcomes produced by machine models in Matlab objects available upon request | Model explainability section, p. 6 |

We combined reporting items from both Senior et al. (2021) and Christodoulou et al. (2019) as they complement one another. For example, Senior et al.’s (2021) is based on PROBAST (Prediction model Risk Of Bias ASsessment Tool) guideline which is not geared specifically toward machine learning methodology. Christodoulou et al. (2019), while targeted explicitly at machine learning, is less comprehensive than Senior et al. (2021).

¹Reporting items based on Senior et al. (2021)

²Reporting items based on Christodoulou et al. (2019)

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Supplementary Table S2 List of PEQ, BSSS-C, PPI and YSR items used as predictors

| | |
|--------|---|
| PEQ1 | My parent often scolds me |
| PEQ2 | Before I finish saying something, my parent often interrupts me |
| PEQ3 | My parent often irritates me |
| PEQ4 | Often there are misunderstandings between my parent and myself |
| PEQ5 | I treat others with more respect than I treat my parent |
| PEQ6 | My parent often hurts my feelings |
| PEQ7 | My parent does not trust me to make my own decisions |
| PEQ8 | My parent and I often get into arguments |
| PEQ9 | I often seem to anger or annoy my parent |
| PEQ10 | My parent often loses her/his temper with me |
| PEQ11 | My parent sometimes hits me in anger |
| PEQ12 | Once in a while I have been really scared of my parents |
| BSSSC1 | I'm interested in almost everything that is new |
| BSSSC2 | I always like to do things that no one else has done before |
| BSSSC3 | I will feel very uncomfortable if I stay in the same place for too long |
| BSSSC4 | I get restless if I do the same thing for a long time |
| BSSSC5 | I would love to make friends with adventurous people |
| BSSSC6 | Going on adventures always makes me happy |
| BSSSC7 | I would do anything as long as it is exciting and stimulating |
| BSSSC8 | To pursue new experiences and excitement, I can go against rules and regulations |
| PPI1 | How often do you feel the need to take the same co-curricular activities (CCAs) that your friends take? |
| PPI2 | How often do you feel the need to be part of a group in school? |
| PPI3 | How often do you feel the need to be friends with the popular students? |
| PPI4 | How often do you feel the need to wear the same style of clothes as your friends? |
| PPI5 | How often do you feel the need to talk or act the same way as your friends? |
| PPI6 | How often do you feel the need to have the same kind of hairstyle like your friends? |
| PPI7 | How often do you feel the need to be good friends only with people your friends like? |
| PPI8 | How often do you feel the need to have the same ideas about things as your friends? |
| PPI9 | How often do you feel the need to listen to music and music groups that your friends think are good? |
| YSR1 | I act too young for my age. |
| YSR2 | I drink alcohol without my parents' approval |
| YSR3 | I argue a lot |
| YSR4 | I don't finish things that I start |
| YSR5 | There is very little that I enjoy |
| YSR8 | I have trouble concentrating or paying attention |
| YSR10 | I have trouble sitting still |
| YSR13 | I feel confused |
| YSR14 | I cry a lot |
| YSR16 | I am mean to others |
| YSR17 | I daydream a lot |
| YSR19 | I try to get a lot of attention |
| YSR20 | I destroy my own things |
| YSR21 | I destroy things belonging to others |
| YSR22 | I disobey my parents |
| YSR23 | I disobey at school |
| YSR26 | I don't feel guilty after doing something I shouldn't |
| YSR28 | I break rules at home, school, or elsewhere |
| YSR29 | I am afraid of certain animals, situations, or places other than school |
| YSR30 | I am afraid of going to school |
| YSR31 | I am afraid I might think or do something bad |
| YSR32 | I feel that I have to be perfect |

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| | |
|--------|--|
| YSR33 | I feel that no one loves me |
| YSR35 | I feel worthless |
| YSR37 | I get in many fights |
| YSR39 | I hang around with kids who get in trouble |
| YSR41 | I act without thinking |
| YSR42 | I would rather be alone than with others |
| YSR43 | I lie or cheat |
| YSR45 | I am nervous or tense |
| YSR47 | I have nightmares |
| YSR50 | I am too fearful or anxious |
| YSR51 | I feel dizzy or lightheaded |
| YSR52 | I feel too guilty |
| YSR54 | I feel overtired without good reason |
| YSR56a | Physical problems without known medical cause: Aches or pains (not stomach or headaches) |
| YSR56b | Physical problems without known medical cause: Headaches |
| YSR56c | Physical problems without known medical cause: Nausea, feel sick |
| YSR56d | Physical problems without known medical cause: Problems with eyes (not if: corrected by glasses) |
| YSR56e | Physical problems without known medical cause: Rashes or other skin problems |
| YSR56f | Physical problems without known medical cause: Stomachaches |
| YSR56g | Physical problems without known medical cause: Vomiting, throwing up |
| YSR56h | Physical problems without known medical cause: Other |
| YSR57 | I physically attack people |
| YSR61 | My school work is poor |
| YSR63 | I would rather be with older kids than kids my own age |
| YSR65 | I refuse to talk |
| YSR67 | I run away from home |
| YSR68 | I scream a lot |
| YSR69 | I am secretive or keeps things to myself |
| YSR71 | I am self-conscious or easily embarrassed |
| YSR75 | I am too shy or timid |
| YSR78 | I cannot concentrate and am easily distracted |
| YSR81 | I steal at home |
| YSR82 | I steal from places other than home |
| YSR86 | I am stubborn |
| YSR87 | My moods or feelings change |
| YSR89 | I am suspicious |
| YSR90 | I swear or use dirty language |
| YSR94 | I tease others a lot |
| YSR95 | I have a hot temper |
| YSR97 | I threaten to hurt people |
| YSR99 | I smoke |
| YSR101 | I cut classes or skip school |
| YSR102 | I don't have much energy |
| YSR103 | I am unhappy, sad, or depressed |
| YSR104 | I am louder than other kids |
| YSR105 | I use drugs |
| YSR111 | I keep from getting involved with others |
| YSR112 | I worry a lot |

Items are not numbered sequentially as only items related to the six narrowband syndrome scales were administered, and we retained the original YSR item numbers.

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Supplementary Table S3 Descriptive statistics of individual predictor and outcome items

| | Mean | Standard deviation | | Mean | Standard deviation |
|--------|------|--------------------|--------|------|--------------------|
| PEQ1 | 2.58 | 0.82 | YSR17 | 0.82 | 0.75 |
| PEQ2 | 2.80 | 0.96 | YSR19 | 0.37 | 0.59 |
| PEQ3 | 2.92 | 0.92 | YSR20 | 0.34 | 0.59 |
| PEQ4 | 2.69 | 0.98 | YSR21 | 0.13 | 0.38 |
| PEQ5 | 3.22 | 0.87 | YSR22 | 0.38 | 0.54 |
| PEQ6 | 3.08 | 0.92 | YSR23 | 0.27 | 0.49 |
| PEQ7 | 2.91 | 0.98 | YSR26 | 0.33 | 0.56 |
| PEQ8 | 3.06 | 0.91 | YSR28 | 0.35 | 0.54 |
| PEQ9 | 2.80 | 0.93 | YSR29 | 0.81 | 0.77 |
| PEQ10 | 2.99 | 0.92 | YSR30 | 0.21 | 0.46 |
| PEQ11 | 3.33 | 0.90 | YSR31 | 0.79 | 0.72 |
| PEQ12 | 2.97 | 1.04 | YSR32 | 0.55 | 0.68 |
| BSSSC1 | 3.68 | 0.85 | YSR33 | 0.48 | 0.64 |
| BSSSC2 | 3.52 | 0.98 | YSR35 | 0.51 | 0.68 |
| BSSSC3 | 3.05 | 1.20 | YSR37 | 0.20 | 0.45 |
| BSSSC4 | 3.68 | 1.09 | YSR39 | 0.23 | 0.47 |
| BSSSC5 | 3.93 | 0.98 | YSR41 | 0.60 | 0.61 |
| BSSSC6 | 3.95 | 1.01 | YSR42 | 0.69 | 0.69 |
| BSSSC7 | 3.93 | 1.02 | YSR43 | 0.46 | 0.57 |
| BSSSC8 | 2.76 | 1.23 | YSR45 | 0.71 | 0.64 |
| PPI1 | 2.54 | 1.05 | YSR47 | 0.60 | 0.69 |
| PPI2 | 2.95 | 1.06 | YSR50 | 0.48 | 0.63 |
| PPI3 | 2.22 | 1.00 | YSR51 | 0.42 | 0.62 |
| PPI4 | 1.83 | 0.91 | YSR52 | 0.29 | 0.53 |
| PPI5 | 1.90 | 0.94 | YSR54 | 0.59 | 0.71 |
| PPI6 | 1.56 | 0.82 | YSR56a | 0.36 | 0.58 |
| PPI7 | 1.95 | 1.01 | YSR56b | 0.58 | 0.66 |
| PPI8 | 2.46 | 1.08 | YSR56c | 0.33 | 0.55 |
| PPI9 | 2.40 | 1.18 | YSR56d | 0.18 | 0.46 |
| YSR1 | 0.69 | 0.60 | YSR56e | 0.27 | 0.56 |
| YSR2 | 0.08 | 0.32 | YSR56f | 0.46 | 0.61 |
| YSR3 | 0.79 | 0.63 | YSR56g | 0.17 | 0.42 |
| YSR4 | 0.74 | 0.59 | YSR56h | 0.06 | 0.31 |
| YSR5 | 0.71 | 0.69 | YSR57 | 0.19 | 0.43 |
| YSR8 | 0.88 | 0.68 | YSR61 | 0.64 | 0.62 |
| YSR10 | 0.73 | 0.73 | YSR63 | 0.48 | 0.64 |
| YSR13 | 0.74 | 0.66 | YSR65 | 0.37 | 0.55 |
| YSR14 | 0.43 | 0.64 | YSR67 | 0.08 | 0.30 |
| YSR16 | 0.44 | 0.56 | YSR68 | 0.41 | 0.62 |

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| | Mean | Standard deviation |
|--------------|-------------|-------------------------------|
| YSR69 | 0.99 | 0.70 |
| YSR71 | 0.86 | 0.73 |
| YSR75 | 0.64 | 0.67 |
| YSR78 | 0.89 | 0.72 |
| YSR81 | 0.07 | 0.29 |
| YSR82 | 0.04 | 0.22 |
| YSR86 | 0.76 | 0.66 |
| YSR87 | 1.06 | 0.70 |
| YSR89 | 0.68 | 0.70 |
| YSR90 | 0.86 | 0.67 |
| YSR94 | 0.57 | 0.63 |
| YSR95 | 0.68 | 0.73 |
| YSR97 | 0.15 | 0.40 |
| YSR99 | 0.04 | 0.25 |
| YSR101 | 0.07 | 0.29 |
| YSR102 | 0.48 | 0.62 |
| YSR103 | 0.53 | 0.65 |
| YSR104 | 0.44 | 0.65 |
| YSR105 | 0.02 | 0.15 |
| YSR111 | 0.48 | 0.61 |
| YSR112 | 0.84 | 0.75 |
| SchEnjoyment | 1.84 | 0.57 |