Future Directions in Sleep and Developmental Psychopathology

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National Jewish Health
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Conflict of Interest Disclosures

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- National Institutes of Health
- Robert Wood Johnson Foundation

Consultant
- Johnson and Johnson

Royalties
What is sleep and why is it important?

Which came first, the chicken or the egg?

Questions for today’s talk

Are developmental changes during sleep important?

Sleep and developmental psychopathology, nature or nurture?

Sleep Primer
What is Sleep?

- Sleep is a behavioral state of perceptual disengagement from and insensitivity to the environment, usually characterized by typical behavioral concomitants:
  - Go to sleep and wake up
  - Tune the world out
  - Lie down with eyes closed
What is Sleep?

- Sleep is a reversible behavioral state of perceptual disengagement from and relative insensitivity to the environment, usually characterized by typical behavioral concomitants.

*Sleep is not an optional luxury, but is essential for health, daytime functioning, and well-being.*

You have to breathe

*You have to eat*

*You have to sleep!*
Sleep is NOT for slackers!

Stages of Sleep

- Stages 0-3: Growth hormone released, brain recovery, executive functioning
- Stages 4: Memory consolidation, learning

0       1        2       3         4        5        6        7        8         9

Hours of Sleep
Process S – Sleep Homeostasis

Sleep need

Wake
Sleep

7a 10p 7a
time of day

Borbely (1982); Van Dongen et al. (2003)

Process C - Circadian Rhythm

Sleep need

Wake
Sleep

7a 10p 7a
time of day

Borbely (1982); Carskadon et al. (1980, 2002)
Circadian Misalignment

[Graph showing sleep need and sleep alignment]

Borbely (1982); Carskadon et al. (1980, 2002)

Recommended Sleep Duration (2016)

<table>
<thead>
<tr>
<th>Age</th>
<th>Sleep Per 24 Hours (*including naps)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infants</td>
<td>4 to 12 months</td>
</tr>
<tr>
<td>Toddlers</td>
<td>1 to 2 years</td>
</tr>
<tr>
<td>Preschoolers</td>
<td>3 to 5 years</td>
</tr>
<tr>
<td>Children</td>
<td>6 to 12 years</td>
</tr>
<tr>
<td>Adolescents</td>
<td>13 to 18 years</td>
</tr>
</tbody>
</table>
Faces Associated with Insufficient Sleep

The Obvious Question

Sleep

Developmental Psychopathology
Future Direction #1
Answering the Obvious Question

Answering the Obvious Question

- Cohort studies
### School Cohort

<table>
<thead>
<tr>
<th>GRADE</th>
<th>FEMALE</th>
<th>WHITE</th>
<th>BLACK</th>
<th>HISPANIC</th>
<th>FREE REDUCED LUNCH</th>
</tr>
</thead>
<tbody>
<tr>
<td>3RD (n=3082)</td>
<td>47.9</td>
<td>54.9</td>
<td>8.8</td>
<td>18.7</td>
<td>30.5</td>
</tr>
<tr>
<td>4TH (n=3090)</td>
<td>46.2</td>
<td>54.4</td>
<td>9.6</td>
<td>18.2</td>
<td>32.1</td>
</tr>
<tr>
<td>5TH (n=3147)</td>
<td>47.5</td>
<td>56.1</td>
<td>9.8</td>
<td>19.3</td>
<td>30.8</td>
</tr>
<tr>
<td>6TH (n=2936)</td>
<td>50.0</td>
<td>54.7</td>
<td>10.7</td>
<td>18.6</td>
<td>30.3</td>
</tr>
<tr>
<td>7TH (n=2768)</td>
<td>49.1</td>
<td>54.8</td>
<td>10.9</td>
<td>18.6</td>
<td>30.5</td>
</tr>
<tr>
<td>8TH (n=2738)</td>
<td>52.7</td>
<td>55.8</td>
<td>9.2</td>
<td>19.1</td>
<td>29.8</td>
</tr>
<tr>
<td>9TH (n=2472)</td>
<td>50.9</td>
<td>53.6</td>
<td>11.2</td>
<td>19.8</td>
<td>31.5</td>
</tr>
<tr>
<td>10TH (n=2004)</td>
<td>52.5</td>
<td>52.9</td>
<td>11.3</td>
<td>18.6</td>
<td>24.5</td>
</tr>
<tr>
<td>11TH (n=1982)</td>
<td>53.9</td>
<td>53.3</td>
<td>11.5</td>
<td>18.2</td>
<td>26.0</td>
</tr>
<tr>
<td>TOTAL (n=24,219)</td>
<td>49.8</td>
<td>54.6</td>
<td>10.2</td>
<td>18.8</td>
<td>29.9</td>
</tr>
</tbody>
</table>
Weekday Sleep Opportunity (Hrs) and Sad in Past 7 Days

<table>
<thead>
<tr>
<th>Level</th>
<th>Never</th>
<th>Almost Never</th>
<th>Sometimes</th>
<th>Almost Always</th>
<th>Always</th>
</tr>
</thead>
<tbody>
<tr>
<td>MIDDLE</td>
<td>8.58</td>
<td>8.53</td>
<td>8.37</td>
<td>8.19</td>
<td>8.05</td>
</tr>
<tr>
<td>HIGH</td>
<td>7.41</td>
<td>7.34</td>
<td>7.17</td>
<td>7.05</td>
<td>7.04</td>
</tr>
</tbody>
</table>

F(4,8307) = 10.66, p < .001 (26 minutes)
F(4,7787) = 37.62, p < .001 (32 minutes)
F(4,5881) = 27.48, p < .001 (22 minutes)

Weekday Sleep Opportunity (Hrs) and Nervous in Past 7 Days

<table>
<thead>
<tr>
<th>Level</th>
<th>Never</th>
<th>Almost Never</th>
<th>Sometimes</th>
<th>Almost Always</th>
<th>Always</th>
</tr>
</thead>
<tbody>
<tr>
<td>ELEMENTARY</td>
<td>9.78</td>
<td>9.82</td>
<td>9.75</td>
<td>9.56</td>
<td>9.41</td>
</tr>
<tr>
<td>MIDDLE</td>
<td>8.53</td>
<td>8.58</td>
<td>8.42</td>
<td>8.29</td>
<td>8.07</td>
</tr>
<tr>
<td>HIGH</td>
<td>7.43</td>
<td>7.34</td>
<td>7.22</td>
<td>7.11</td>
<td>7.05</td>
</tr>
</tbody>
</table>

F(4,8263) = 7.07, p < .001 (24 minutes)
F(4,7759) = 26.69, p < .001 (28 minutes)
F(4,5881) = 27.48, p < .001 (23 minutes)
Weekday Sleep Opportunity (Hrs) and Worried in Past 7 Days

<table>
<thead>
<tr>
<th>Never</th>
<th>Almost Never</th>
<th>Sometimes</th>
<th>Almost Always</th>
<th>Always</th>
</tr>
</thead>
<tbody>
<tr>
<td>ELEMENTARY</td>
<td>9.78</td>
<td>9.84</td>
<td>9.73</td>
<td>9.66</td>
</tr>
<tr>
<td>MIDDLE</td>
<td>8.57</td>
<td>8.58</td>
<td>8.39</td>
<td>8.25</td>
</tr>
<tr>
<td>HIGH</td>
<td>7.42</td>
<td>7.37</td>
<td>7.27</td>
<td>7.09</td>
</tr>
</tbody>
</table>

- *F*(4,8246) = 12.02, *p* < .001
- *F*(4,7750) = 35.50, *p* < .001
- *F*(4,5863) = 31.19, *p* < .001

31 minutes
28 minutes
27 minutes

Answering the Obvious Question

- Cohort studies
- Prospective studies
The Prospective Association between Sleep Deprivation and Depression among Adolescents

Is there an association between short sleep duration and adolescent anxiety disorders?

Robert E. Roberts, PhD \( ^{a} \), Hao T. Duong, MD, MPH, DrPH \( ^{b} \)

*Sleep Medicine* (2017)

**Baseline**
- Short Sleep Duration (≤ 6 hours)
- Major Depression
- Depressive Sxs
- Anxiety Disorders

**One-Year Later**
- Major Depression
- Depressive Sxs
- Anxiety Disorders
- Short Sleep Duration (≤ 6 hours)

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Answering the Obvious Question

- Cohort studies
- Prospective studies
- Sleep manipulation protocols
**Impact of Sleep Extension and Restriction on Children’s Emotional Lability and Impulsivity**

Authors: Feut Gruber, Ph.D.,* Jamie Cassoff, BSc.,* Sonia Frenette, Ph.D.,* Sabrina Wiebe, MSc.,* and Julie Garrier, Ph.D.,*

Baseline Sleep (5 nights) via actigraphy

- **Sleep Extension** (+1 h sleep, 5 nights) (n=17)
  - 27 min increase

- **Sleep Restriction** (-1 h sleep, 5 nights) (n=16)
  - 54 min decrease

**Table 3** Teacher-Reported CDT-T Scores of Children After Baseline and Sleep Manipulation

<table>
<thead>
<tr>
<th>CDT-T Scores</th>
<th>Sleep-Extension Group</th>
<th>Sleep-Restriction Group</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Baseline</td>
<td>After Sleep Manipulation</td>
</tr>
<tr>
<td>Emotional lability subscale</td>
<td>50.33 (8.29)</td>
<td>47.33 (4.65)</td>
</tr>
<tr>
<td>Restless-impulsive behavior</td>
<td>49.94 (9.32)</td>
<td>47.05 (5.94)</td>
</tr>
<tr>
<td>subscale</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total score</td>
<td>49.89 (8.19)</td>
<td>46.67 (5.36)</td>
</tr>
</tbody>
</table>

Data are given as mean (SD).

**Impact of sleep restriction versus idealized sleep on emotional experience, reactivity and regulation in healthy adolescents**

Radhika Reddy, Cara A. Palmer, Christine Jackson, Samantha G. Farris, and Candice A. Alfano

Baseline Sleep (6 nights) via actigraphy

- **Ideal Sleep** (9.5 h TIB, 1 night)

- **Sleep Restriction** (4 h TIB, 1 night)

Lab based emotional reactivity

Cognitive reappraisal

Table 4 Descriptive means for emotional reactivity variables for the full sample and two sleep conditions and comparisons between sleep groups

<table>
<thead>
<tr>
<th>Variable</th>
<th>Full sample (N = 40)</th>
<th>Restricted sleep group (n = 20)</th>
<th>Idealized sleep group (n = 20)</th>
<th>F, p, ns</th>
<th>η² (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Valence</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Negative</td>
<td>3.06 (0.75)</td>
<td>2.84 (0.90)</td>
<td>3.27 (0.77)</td>
<td>3.72</td>
<td>0.09 (0.01, 0.62), 0.06</td>
</tr>
<tr>
<td>Neutral</td>
<td>5.10 (0.38)</td>
<td>5.05 (0.32)</td>
<td>5.16 (0.44)</td>
<td>0.91</td>
<td>0.02 (0.01, 0.14), 0.35</td>
</tr>
<tr>
<td>Positive</td>
<td>7.59 (0.84)</td>
<td>7.51 (0.68)</td>
<td>7.67 (0.98)</td>
<td>0.95</td>
<td>0.01 (0.01, 0.10), 0.56</td>
</tr>
<tr>
<td>Intensity/arousal</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Negative</td>
<td>4.58 (1.69)</td>
<td>4.27 (1.81)</td>
<td>4.89 (1.54)</td>
<td>1.41</td>
<td>0.03 (0.01, 0.16), 0.24</td>
</tr>
<tr>
<td>Neutral</td>
<td>1.99 (1.22)</td>
<td>1.76 (1.85)</td>
<td>2.22 (1.49)</td>
<td>1.50</td>
<td>0.04 (0.01, 0.18), 0.23</td>
</tr>
<tr>
<td>Positive</td>
<td>4.83 (2.08)</td>
<td>4.51 (1.87)</td>
<td>5.15 (2.24)</td>
<td>1.00</td>
<td>0.02 (0.01, 0.14), 0.32</td>
</tr>
</tbody>
</table>

Higher valence rating = more positive valence; Higher intensity/arousal rating = greater intensity/arousal. Means for negative images presented here were based on negative view images only. SD, standard deviation; CI, confidence interval.
Sleep restriction worsens mood and emotion regulation in adolescents

Katherine T. Baum, Anjali Desai, Julie Field, Lauren E. Miller, Joseph Rausch, and Dean W. Beebe

Baseline Sleep (7 nights) via actigraphy

Sleep Extension (10.5 h TIB, 5 nights) → Sleep Restriction (6.5 h TIB, 5 nights) → Sleep Extension (10.5 h TIB, 5 nights)

Sleep Restriction (6.5 h TIB, 5 nights) → Sleep Extension (10.5 h TIB, 5 nights)

Self-report POMS median raw scores (Vigor reverse scored)

Population based studies highlight important associations
Prospective studies help us understand directionality
Sleep manipulation protocols identify underlying mechanisms
Future Direction #2
What Goes on During Sleep?

The Future
NEXT EXIT

Mapping of Cortical Activity in the First Two Decades of Life: A High-Density Sleep Electroencephalogram Study
Salome Kurth,1 Maya Ringli,2 Anja Geiger,3,4 Monique Lebourgeois,3,4 Oskar G. Jenni,1,3,5 and Reto Huber1,3,6
J Neurosci (2010)

Mapping the electrophysiological marker of sleep depth reveals skill maturation in children and adolescents
Salome Kurth1, Maya Ringli2, Monique K. Lebourgeois3,4, Anja Geiger3, Andreas Buchmann3, Oskar G. Jenni3,5, Reto Huber4,6,7
Neuroimage (2012)

2-5 y 5-8 y 8-11 y 11-14 y 14-17 y 17-20 y

SWA

Minimal Power Maximal Power

B

C

VISION VISUOMOTOR
SIMPLE MOTOR COMPLEX MOTOR
LANGUAGE COGNITIVE CONTROL

Age (years)

6 10 15 20
Topography of sleep slow wave activity in children with attention-deficit/hyperactivity disorder

Maya Rin gla a, Soraya Souissi a, Salomé Kurth a, Daniel Brandes b,d, Oskar G. Jenni a,b,d, and Reto Huber a,d,c,f,

Cortex (2013)

ADHD
(11.8y ± .4)

Controls
(11.6y ± .5)

Increased frontal sleep slow wave activity in adolescents with major depression

Noemi Teslerab, Miriam Gerstenbergc, Maurizia Frascinib, Oskar G. Jennib,d, Susanne Walitza b,c,d, Reto Huberb,cd

Neuroimage: Clinical (2016)

Depressed

Controls

age 15.1±0.3 years

age 15.3±0.3 years

max

min
Future Direction #2

What Goes on During Sleep?

- How can learning about biological changes during sleep across development assist with the diagnosis and treatment of psychopathology?
Future Direction #3
Nature vs. Nurture

The Direction of Longitudinal Associations Between Sleep Problems and Depression Symptoms: A Study of Twins Aged 8 and 10 Years

- Genetics most important in explaining stability of sleep problems
- Non-shared environment strongest influence on stability of depression
- Early treatment of sleep problems might protect against depression
Heritability of insomnia moderate (genetic factors accounted for 37% of variance)
- Heritability of overanxious disorder: 30% M / 46% F
- Heritability of depression: 11% M / 19% F

Childhood ADHD predicted poor sleep quality in young adulthood
- After adjusting for adult ADHD diagnosis, childhood ADHD no longer associated with sleep quality at age 18 years

**If childhood ADHD remits, no increased risk of sleep problems as young adult**

Young adult ADHD associated with poor sleep quality, due to genetic (55%) and non-shared environmental (45%) influences
Adolescents need 8.5 to 9.25 hours of sleep per night

7 out of 10 adolescents in the US get 7 hours or less per night


Extrinsic Sleep Disruptors
**Goal SH-3:** Increase the proportion of students in grades 9 through 12 who get sufficient sleep (8 or more hours of sleep on an average school night)

- **Baseline:** 30.9%  
  **Target:** 33.1%

- Sleep health education
- Changing school start times

---

**Cherry Creek School District:** Changing School Start Times

<table>
<thead>
<tr>
<th></th>
<th>2016 – 2017</th>
<th>2017 - 2018</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>7:10 a.m. to 2:30-2:51 p.m.</td>
<td>8:20 a.m. to 3:30 p.m.</td>
</tr>
</tbody>
</table>

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Cherry Creek School District: Changing School Start Times

<table>
<thead>
<tr>
<th></th>
<th>2016 – 2017</th>
<th>2017 - 2018</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>7:10 a.m. to 2:30-2:51 p.m.</td>
<td>8:20 a.m. to 3:30 p.m.</td>
</tr>
<tr>
<td>Middle</td>
<td>7:50-8:10 a.m. to 2:50-3:10 p.m.</td>
<td>8:50 a.m. to 3:45 p.m.</td>
</tr>
<tr>
<td>Elementary</td>
<td>9:00 a.m. to 3:30 p.m.</td>
<td>8:00 a.m. to 2:45 p.m.</td>
</tr>
</tbody>
</table>

- Multi-method pre-post evaluation implemented
  - Surveys
  - Focus groups and open-ended surveys (including mental health team)
  - District level data (i.e., attendance, tardies, nursing records)
  - Community data (e.g., CDOT, law enforcement)
Cherry Creek School District: Changing School Start Times

- Reported bedtime and wake time for weekday and weekend
- PROMIS items for sleep, mood, health
- Additional questions about physical and academic health

<table>
<thead>
<tr>
<th>Sample</th>
<th>2017</th>
<th>2018</th>
</tr>
</thead>
<tbody>
<tr>
<td>All Students</td>
<td>25,446 (71%)</td>
<td>30,946 (76%)</td>
</tr>
<tr>
<td>Cohort Students</td>
<td>5327 (21%)</td>
<td>TBD</td>
</tr>
<tr>
<td>Parents</td>
<td>14,776 (32%)</td>
<td>11,144 (24%)</td>
</tr>
<tr>
<td>Staff</td>
<td>1,864 (53%)</td>
<td>2109 (58%)</td>
</tr>
</tbody>
</table>

Sleep Timing/Wake Time is Driven by School Start Times (pre)

- Bedtimes increase steadily with increasing grade
  - ES → MS: 40 m, MS → HS: 34 m
- Wake times consistent across school level

Bedtime (24 hour clock)

Wake Time (clock time)
Sleep Timing/Duration is Driven by School Start Times (pre)

- Deficient sleep in high school students
  - 26.8% >8 hours of sleep

WD Sleep Opportunity (hrs)

- Significant oversleep in older students
  - 2+ hours sleep deprivation

WE Oversleep (hrs)

Sleep Timing/Wake Time is Driven by School Start Times (pre/post)

- Bedtimes increase steadily with increasing grade
  - ES → MS: 40 m, MS → HS: 34 m
  - ES → MS: 66 m, MS → HS: 32 m

Bedtime (24 hour clock)

- Wake times consistent across school level

Wake Time (clock time)
Sleep Timing/Duration is Driven by School Start Times (pre/post)

- Changes in weekday sleep opportunity
  - ES: -22 m, MS: +12 m, HS: +44 m

- Changes in amount of weekend oversleep
  - ES: +20 m, MS: -25 m, HS: -64 m

Sleep and Health Outcomes

Percent students reporting symptom in past 7 days

<table>
<thead>
<tr>
<th>Year</th>
<th>Elementary</th>
<th>Middle</th>
<th>High</th>
<th>Elementary</th>
<th>Middle</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>2017</td>
<td>-0.6%</td>
<td>1.9%</td>
<td>-3.5%</td>
<td>-1.1%</td>
<td>2.2%</td>
<td>-1.1%</td>
</tr>
<tr>
<td>2018</td>
<td>1.1%</td>
<td>1.1%</td>
<td>-7.4%</td>
<td>-0.9%</td>
<td>1.1%</td>
<td>-7.4%</td>
</tr>
</tbody>
</table>

N=226
N=322
N=484
**Goal SH-3:** Increase the proportion of students in grades 9 through 12 who get sufficient sleep (8 or more hours of sleep on an average school night)

<table>
<thead>
<tr>
<th>Sample</th>
<th>Baseline</th>
<th>Goal</th>
<th>Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Healthy People 2020</td>
<td>30.9</td>
<td>33.1</td>
<td>+2.2</td>
</tr>
</tbody>
</table>

**Goal SH-3:** Increase the proportion of students in grades 9 through 12 who get sufficient sleep (8 or more hours of sleep on an average school night)

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<th>Goal/2018</th>
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<tr>
<td>Healthy People 2020</td>
<td>30.9</td>
<td>33.1</td>
<td>+2.2</td>
</tr>
<tr>
<td>CCSD</td>
<td>26.8</td>
<td>57.7</td>
<td>+30.9</td>
</tr>
</tbody>
</table>
### Nat’l Longitudinal Study of Adolescent Health

<table>
<thead>
<tr>
<th>Bedtime</th>
<th>Unadjusted</th>
<th>Adjusted</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 pm or earlier</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>By 11:00 pm</td>
<td>1.15 (0.94-1.40)</td>
<td>1.13 (0.90-1.42)</td>
</tr>
<tr>
<td>By or after midnight</td>
<td>1.42 (1.21-1.67)</td>
<td>1.28 (1.07-1.52)</td>
</tr>
</tbody>
</table>
### Nat’l Longitudinal Study of Adolescent Health

#### ODDS RATIOS (95% CI) FOR DEPRESSION

<table>
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<td>By or after midnight</td>
<td>1.42 (1.21-1.67)</td>
<td>1.28 (1.07-1.52)</td>
</tr>
</tbody>
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#### ODDS RATIOS (95% CI) FOR SUICIDAL IDEATION

<table>
<thead>
<tr>
<th>Bedtime</th>
<th>Unadjusted</th>
<th>Adjusted</th>
</tr>
</thead>
<tbody>
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</tr>
<tr>
<td>By 11:00 pm</td>
<td>1.15 (0.98-1.35)</td>
<td>1.15 (0.98-1.36)</td>
</tr>
<tr>
<td>By or after midnight</td>
<td>1.30 (1.13-1.49)</td>
<td>1.25 (1.07-1.45)</td>
</tr>
</tbody>
</table>
Future Direction #3
Nature vs. Nurture

▪ Need better understanding of unique genetic and non-shared contributions to sleep and developmental psychopathology

▪ Environmental factors, both within and beyond youth’s control, contribute to sleep and daytime functioning

▪ Critical need to educate youth, families, and education systems about importance of sufficient sleep and healthy sleep habits

More Future Directions

▪ Role of night-to-night variability
▪ Contribution of circadian rhythm
▪ Individual vulnerabilities to sleep loss
▪ Treating comorbid sleep/psych issues
  ▪ Transdiagnostic
  ▪ Medications for sleep/psych
What we know

What we need to learn

Sleep is a critical health asset, required for optimal health and well-being

Complex, bidirectional relationship between sleep and developmental psychopathology

Questions for today’s talk

Developmental, sleep-related changes during sleep may assist with diagnosis and treatment

Both genetic and environmental factors contribute to sleep and psychopathology
Thank You!!

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