Actigraphy Editing Standardization

Christopher E. Kline, Ph.D.
Assistant Professor
Department of Health and Physical Activity
University of Pittsburgh

Translational Research Training in Sleep Medicine
T32 Seminar
November 8, 2019

Actigraphy

- Non-invasive, unobtrusive way to estimate sleep/wake behavior over long periods of time
- Popular and commonly used
  - Research- or clinical-based devices
  - Commercial devices
- Lack of standardization or guidelines on collection, management, and reporting of actigraphy data

Use of actigraphy for assessment in pediatric sleep research
Meltzer et al., *Sleep Med Rev* 2012

"…Other notable findings from this review include the lack of standard scoring rules or variable definitions…"

Table 5
Proposed standard checklist for reporting actigraphy in pediatric sleep research literature.

	Check
Device/System information	
• The name of the device, the specific model, and the name (and location) of the manufacturer.	
• The placement of the device (non-dominant or dominant wrist, left or right ankle, etc.).	
• The measured epoch length, the mode of data collection (e.g., ZCM, TAT, PIM, or TRI), the use of the event marker, and the algorithm or wake sensitivity threshold.	
• Justification for the algorithm that is chosen	
• The type and version of software used.	
• Include information on sensitivity and specificity.	
Sleep diary	
• Type of sleep diary used (e.g., paper, electronic, telephone call)	
• Who completed sleep diary (i.e., parent, child)	
• Frequency of diary completion (e.g., at bedtime only, morning and evening)	
Data collection and processing (including missing data)	
• Number of nights of data collection	
• Number of weekday and weekend nights (if relevant)	
• Methods used to identify and handle artifact	
• How much data lost due to:	
○ Technical failure	
○ Participant non-adherence (to wearing the watch or completing the sleep diary)	
○ Artifact	
Data variables	
• Clearly define the variables, including ones automatically calculated by manufacturer scoring programs (e.g., sleep bouts, wake bouts, motionless sleep or immobile time, circadian parameters)	
• Clearly define the scoring rules used, using common/standardized names	

Note: PIM = proportional integration mode, TAT = time above threshold, TRI = tri-axial mode, ZCM = zero crossing mode.

The SBSM Guide to Actigraphy Monitoring: Clinical and Research Applications

Sonia Ancoli-Israel, PhD
Departments of Psychiatry and Medicine, University of California, San Diego

Behavioral Sleep Medicine, 13:S4–S38, 2015

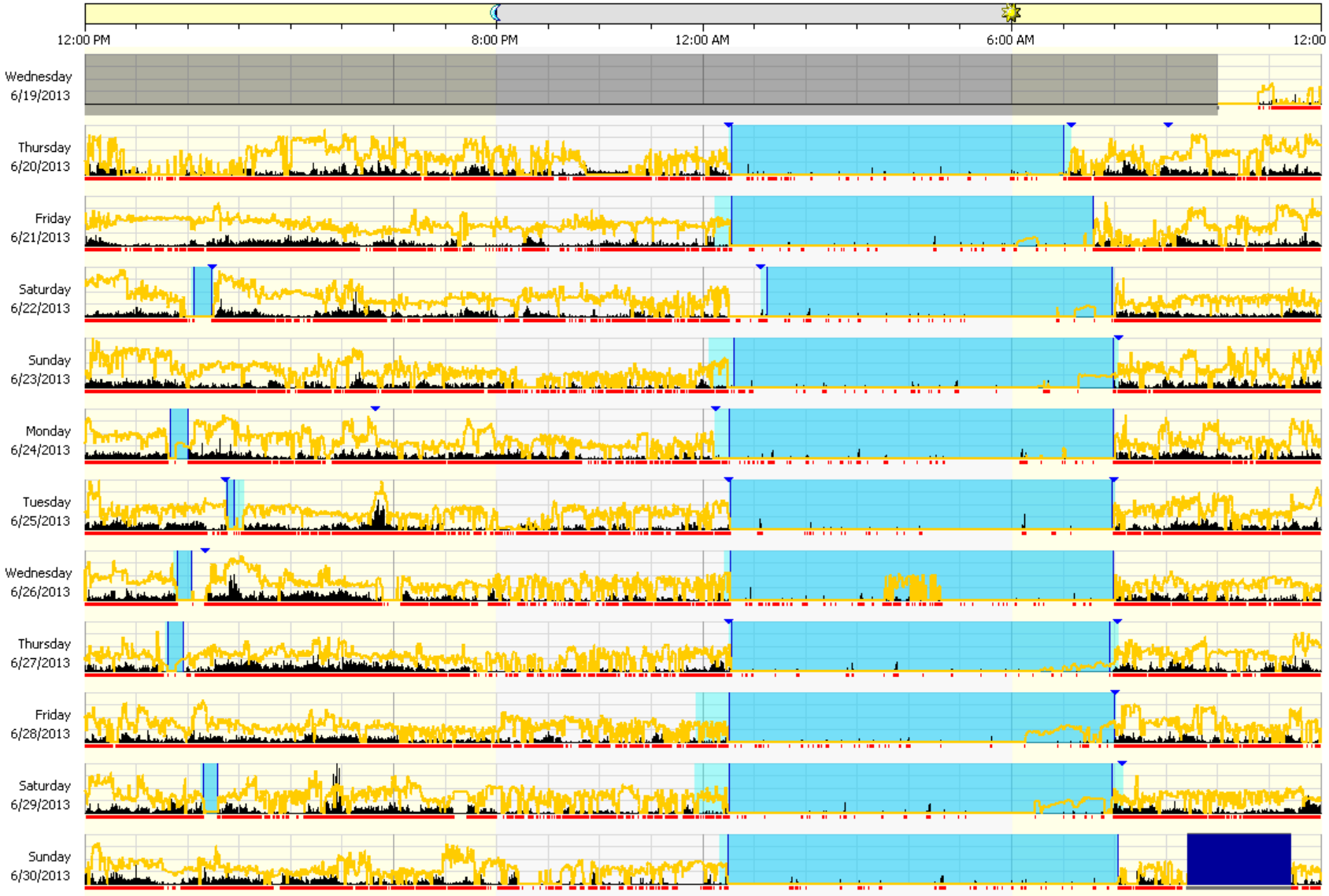
ISSN: 1540-2002 print/1540-2010 online
DOI: 10.1080/15402002.2015.1046356

- "scoring and instruction manual" for actigraphy
- Broad overview of all actigraphy devices—provides basic guidance regarding considerations for actigraphy editing

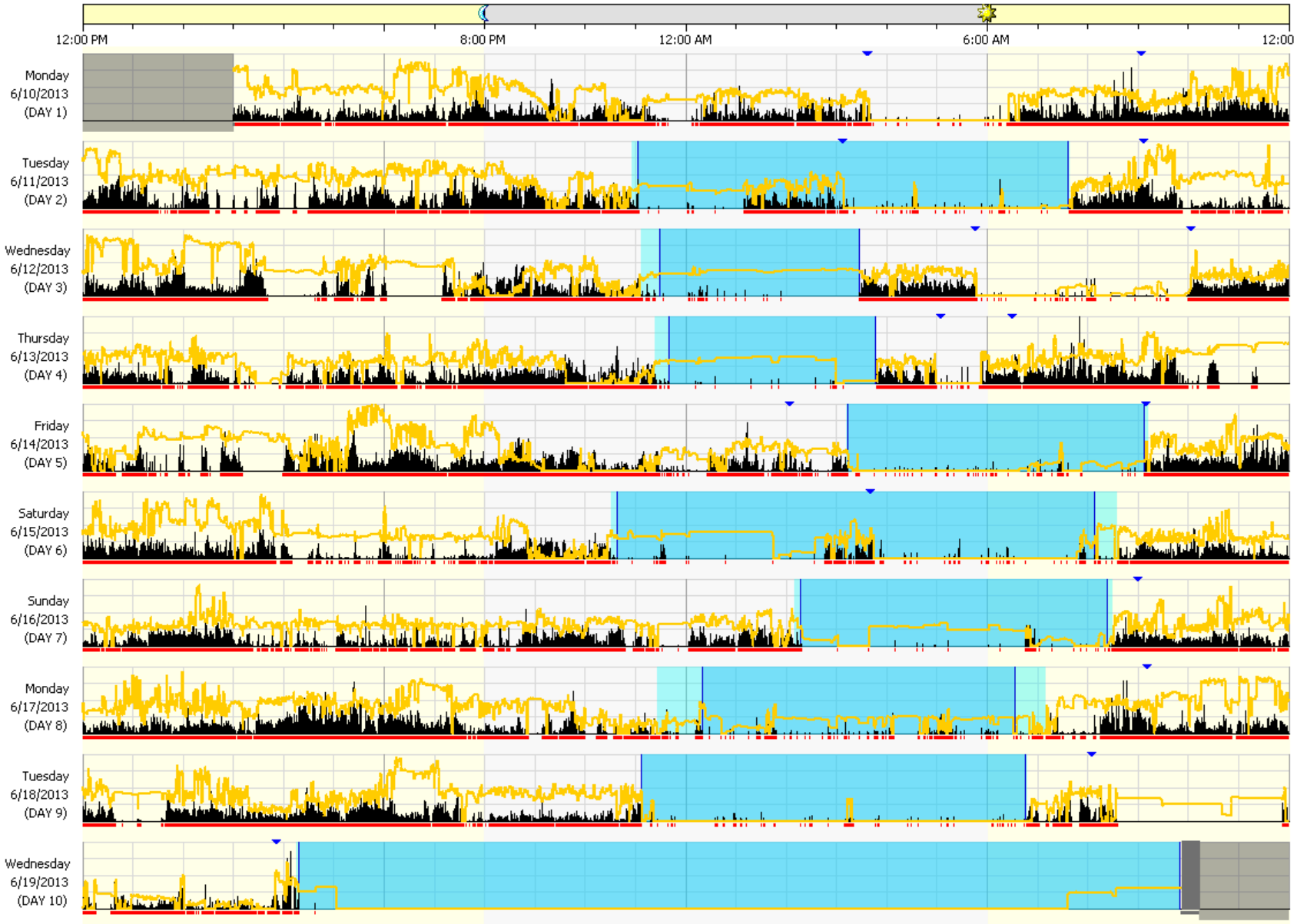
Standardized editing procedures

- Extremely rare for research publications to describe methods used to edit actigraphy data
  - Could potentially lead to (significant??) differences in actigraphy output
  - Minimizes comparability across studies
- Standardized procedures allow for:
  - Replication by other research groups
  - Replication by other scorers in the same research group

The good…


12:00 PM
8:00 PM
12:00 AM
6:00 AM
12:00 PM
Wednesday 6/19/2013
Thursday 6/20/2013
Friday 6/21/2013
Saturday 6/22/2013
Sunday 6/23/2013
Monday 6/24/2013
Tuesday 6/25/2013
Wednesday 6/26/2013
Thursday 6/27/2013
Friday 6/28/2013
Saturday 6/29/2013
Sunday 6/30/2013

The bad…


12:00 PM
8:00 PM
12:00 AM
6:00 AM
12:00 PM
Monday
6/10/2013
(DAY 1)
Tuesday
6/11/2013
(DAY 2)
Wednesday
6/12/2013
(DAY 3)
Thursday
6/13/2013
(DAY 4)
Friday
6/14/2013
(DAY 5)
Saturday
6/15/2013
(DAY 6)
Sunday
6/16/2013
(DAY 7)
Monday
6/17/2013
(DAY 8)
Tuesday
6/18/2013
(DAY 9)
Wednesday
6/19/2013
(DAY 10)

The ugly…


12:00 PM
8:00 PM
12:00 AM
6:00 AM
12:00 PM
Thursday
1/15/2015
(DAY 1)
Friday
1/16/2015
(DAY 2)
Saturday
1/17/2015
(DAY 3)
Sunday
1/18/2015
(DAY 4)
Monday
1/19/2015
(DAY 5)
Tuesday
1/20/2015
(DAY 6)
Wednesday
1/21/2015
(DAY 7)
Thursday
1/22/2015
(DAY 8)
Friday
1/23/2015
(DAY 9)
Saturday
1/24/2015
(DAY 10)

Basic approaches to setting rest intervals

- DIARY: diary reports of bed- and rise-times are used to set the rest interval
  - PRO: incorporates participant's information, so (in theory) should be the best approach
  - CON: impossible to know whether diary was completed immediately after waking; often are crude estimates of actual bed- and rise-times; time-intensive

Setting rest intervals (2)

- EVENT MARKER: press event marker when going to bed and when waking up
  - PRO: simple, accurate method for rest interval identification; minimal time spent on editing
  - CON: dependent upon participant adherence; if initially forgotten, participant may belatedly press event marker (usually easily discernible with visual inspection)

Setting rest intervals (3)

- AUTOMATED ALGORITHM: some software programs have proprietary algorithms that automatically set rest intervals based upon activity data without regard to light data, event markers, or sleep diary reports
  - PRO: automated, so manually setting rest intervals is unnecessary
  - CON: could be problematic in individuals with low daytime activity levels or who are very sedentary in hours leading up to bedtime

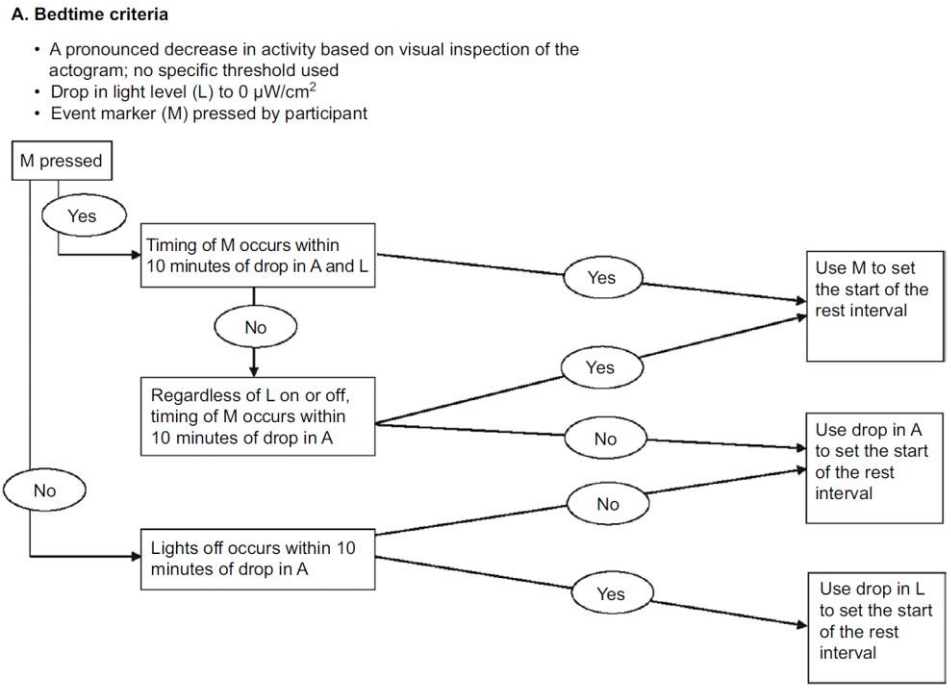
Setting rest intervals (4)

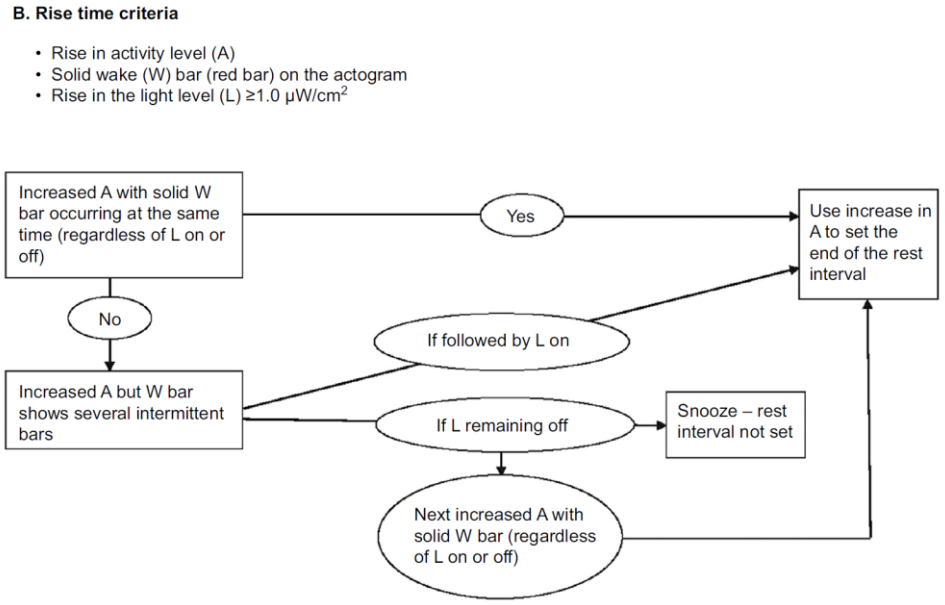
- AUTOMATED ALGORITHM WITH EVENT MARKER: proprietary software automatically sets rest interval, but initially defers to event markers for identification of beginning and end of interval; if event marker is within 30 minutes of the algorithm-identified setpoint, the event marker is used—if the event marker is > 30 minutes from the algorithm-identified setpoint or no event marker was used, automated setpoint is used
  - PRO: combines advantages of 'event marker' and 'automated algorithm' approaches
  - CON: not available with many software packages

Setting rest intervals (5)

- VISUAL INSPECTION/MANUAL SETTING: trained technician manually sets rest intervals based upon close visual inspection of the record, relying upon light and activity data and using event markers and diary reports as supplemental sources of information
  - PRO: likely produces most accurate data
  - CON: significant time commitment; significant amount of subjective judgment involved; significant training needed; inter-technician reliability needs to be established if multiple scorers

Chow approach (10 adolescents, Actiwatch 2)





General hierarchy:
M > L > A

General hierarchy:
Scored wake > L, A
(no M use in morning?)

Diary reports not incorporated into this approach

Chow et al., *Nat Sci Sleep* 2016

Patel approach

- Hierarchy of inputs: event markers, sleep diary, white light intensity, activity
- Start and end of each rest interval are determined based upon each input *in isolation*
  - Event marker: time event marker was pressed
  - Light: < 1 lux for ≥ 5 consecutive epochs
    - Morning light may be unreliable due to morning sunlight
  - Activity: 0 counts for ≥ 5 consecutive epochs
  - Diary: entry for bedtime, rise time
  - If input not available, not factored into decision

Patel approach (continued)

- Concordance across inputs established
  - If ≥ 2 inputs agree within 15 min, highest-ranking input among those in concordance is used
  - If no pair of inputs agree within 15 min, extend concordance to 30 min
  - If no pair of inputs agree within 30 min, activity used to define start and end of rest interval
- Napping data handled similarly
  - Diary or event marker were necessary to consider scoring a nap
  - Daytime periods of low activity and/or low light were insufficient to consider scoring a nap

Modified Patel approach

- After consultation, modified the hierarchy of inputs:
  - Event marker
  - White light
  - Diary
  - Activity

Does the editing method matter?

- Boudebesse et al., *Behav Sleep Med* 2013
  - 18 adults with bipolar disorder
  - When comparing sleep parameter outputs across 5 different rest interval editing methods:
    - Automated algorithm: longer rest interval (≤ 75 min), greater TST (≤ 63 min) and WASO (≤ 10 min)
    - Visual inspection: shorter SOL (≤ 15 min), greater SE (≤ 6%)
  - When considering time and effort:
    - Auto algorithm, auto w/ event marker: ~15 min per record
    - Others: ~25 min per record

Does the editing method matter?

- 1022 nights (N=72 adults, 27 w/ insomnia)
- Compared 4 different approaches: diary, automated only, automated w/ event marker, modified Patel approach
- Relative to modified Patel approach:
  - Bedtime 2.4% earlier (auto), 0.4% earlier (auto+e)
  - Rise time 2.4% later (auto), 0.6% later (diary)
  - Time in bed 8.5% longer (auto)
  - SOL 98.6% greater (auto), 19.7% greater (diary), 17.7% greater (auto+e)
  - WASO 20.6% greater (auto)
  - SE 3.0% lower (auto), 1.7% lower (diary), 0.8% lower (auto+e)
- *Preliminary conclusion*: reliance on automated algorithm is not advised

Standardized editing approaches

- High intra- and inter-scorer reliability often observed when using standardized approach
  - Patel 2015: intra-scorer and inter-scorer ICCs > 0.94 for all sleep measures but SOL (ICC = .91)
  - Chow 2016: inter-scorer ICC for bedtime and rise time 0.975 and 0.995, respectively

Event marker usage

- Ustinov & Lichstein, *Behav Sleep Med* 2013
  - 2100 nights from 60 normal sleepers (5 wk each)
  - 9.8% of nights were missing bedtime event markers
  - 8.2% of nights were missing risetime event markers
  - Frequency of missing data increased with increasing wear duration
- Withrow et al., J Sleep Res 2019
  - 210 nights (N=30 adults with insomnia)
  - 21% of nights missing one or both event markers
- Zibrandtsen et al., *J Sleep Res* 2019
  - 2117 nights (N=150 sleep clinic patients)
  - ~50% compliance each with evening and morning event markers
  - Sex, age, socioeconomic status associated with compliance

Standardized procedures for non-Actiwatch devices?

- Actiwatch provides more input options than most other actigraphy devices
  - Light, event marker, activity (+ diary if used)
- Have not seen standardized procedures published for non-Actiwatch devices
- Example: ActiGraph GT9X
  - No light channel
  - No event marker option
  - Activity, diary are only potential inputs (lowest ranking inputs in 'modified Patel' approach)

Questions?

Christopher E. Kline, PhD
Assistant Professor
Department of Health and Physical Activity
University of Pittsburgh
32 Oak Hill Court, Room 227
Pittsburgh, PA 15261
T: 412-383-4027
E: chriskline@pitt.edu