Chronic sleep reduction in adolescents
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“A well-spent day brings happy sleep.”

-Leonardo da Vinci-
Chapter 3

The Chronic Sleep Reduction Questionnaire (CSRQ): a cross-cultural comparison and validation in Dutch and Australian adolescents

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Abstract

Although adolescents often experience insufficient and/or poor sleep, sleep variables such as total sleep time do not account for individuals’ sleep need and sleep debt and may therefore be an inadequate representation of adolescents’ sleep problems and their daytime consequences. This problem can be overcome by using the Chronic Sleep Reduction Questionnaire (CSRQ), an assessment tool that measures symptoms of chronic sleep reduction and therefore accounting for sleep need and sleep debt. The present study aims at developing an English version of the CSRQ and assesses the reliability and validity of the Dutch and the English CSRQ version. The CSRQ was administered in large Dutch (n = 166, age = 15.2 ± 0.57 years, 28% male) and Australian (n = 236, age = 15.5 ± 0.99 years, 65% males) samples. Subjective sleep variables were measured with surveys and sleep diaries of five school nights. Additionally, sleep of the same five nights was monitored with actigraphy. Both CSRQ versions showed good psychometric properties concerning their reliability (Dutch: α = 0.85; English: α = 0.87) and validity as the same overall structure of the two CSRQ versions and significant correlations with subjective and objective sleep variables were found. School grades were related to chronic sleep reduction, whereas the relationship between grades and other sleep variables was weak or absent. These results highlight the idea that chronic sleep reduction may be a better indicator of adolescents’ insufficient and/or poor sleep than other sleep variables such as total sleep time.
3.1. Introduction

Adolescents sleep less than younger children, although it has been shown that their objective need for sleep does not decrease during the pubertal transition (Carskadon et al., 1993). Eleven to 47% of adolescents report poor sleep (Liu and Zhou, 2002; Russo et al., 2007), and more than 50% sleep less than the ideal 9 h per night (Gibson et al., 2006). This phenomenon can be caused by an interaction of intrinsic (e.g. puberty, circadian and/or homeostatic changes) and extrinsic factors (e.g. social pressure, academic workload) causing later bedtimes, while rise times remain unchanged due to early school start times (Wolfson and Carskadon, 2003). As most adolescents experience these sleep problems over a long period of time, it can be assumed that many suffer from chronically reduced sleep (Loessl et al., 2008; Meijer, 2008). Over time, chronic sleep reduction can result in severe psychological and physiological consequences, such as behavioural problems, poor emotional wellbeing, impaired cognitive and school performance and even detrimental neurobiological changes (Curcio et al., 2006; Mitru et al., 2002; Moore and Meltzer, 2008; Wolfson and Carskadon, 2003).

The problem of chronic sleep reduction during adolescence is a worldwide existing and well-known phenomenon. However, due to a lack of consensus concerning the definition and operationalisation of chronic sleep reduction, studies differ in methodology with most studies using shortened or restricted sleep during a few nights (Roberts et al., 2011; van Dongen et al., 2003a,b). A reliable and valid instrument assessing chronic sleep reduction in adolescents may contribute highly to the comparability and replicability of data. Furthermore, such an assessment tool is needed for educational and clinical purposes in order to measure chronic sleep reduction and its severe consequences on adolescents’ daytime functioning.

Although shortened sleep is often present during adolescence, sleep duration may not always be the best indicator of adolescents’ chronic sleep reduction, with studies reporting severe effects of sleepiness [but not total sleep time (TST)] on different aspects of daytime functioning (e.g. school performance, cognitive functioning) (Anderson et al., 2009; Moore and Meltzer, 2008; Moore et al., 2009). One possible explanation could be that insufficient sleep, leading to sleep debt, has to be interpreted in reference to one’s individual sleep need (Anderson et al., 2009; Moore et al., 2009; van Dongen et al., 2003a,b). However, complex concepts such as sleep debt or sleep need are often difficult to operationalise, especially in non-controlled laboratory studies. Because the manifestation of sleep debt in relation to one’s sleep need is evident in the symptoms of insufficient sleep, it has been speculated that symptoms of chronic sleep reduction that are present during the day give a more accurate picture of chronic sleep reduction than measures of total sleep time or sleep quality itself. Therefore, Meijer (2008) developed the Chronic Sleep Reduction Questionnaire.
(CSRQ). The CSRQ, consisting of the subscales ‘shortness of sleep’, ‘irritation’, ‘loss of energy’ and ‘sleepiness’, assesses chronic sleep reduction by measuring its symptoms throughout the day. The four subscales of the CSRQ are based on existing research investigating the (long-term) symptoms of insufficient and/or poor sleep in adolescents. The subscale ‘shortness of sleep’ comes from evidence showing that restricted sleep in adolescents is not only prevalent but even becomes chronic in up to 54% of adolescents (Roberts et al., 2011). These findings indicate that restricted sleep is an important aspect of chronic sleep reduction. The subscale ‘sleepiness’ is based on research showing that daytime sleepiness is one of the most obvious and direct effects of insufficient and/or poor sleep (Dahl, 1999; Millman, 2005; Pilcher et al., 1997) that can impair individuals’ daytime functioning (e.g. cognitive functioning, school performance). Furthermore, long-term effects of insufficient and/or poor sleep affect individuals’ physical and emotional wellbeing, resulting in the subscales ‘loss of energy’ and ‘irritation’ (Dahl, 1999, 2006; Millman, 2005; Pilcher et al., 1997).

The CSRQ has been tested in Dutch (pre)adolescents (Meijer, 2008) and represents an easy and cost-efficient way to assess symptoms of chronic sleep reduction. However, in order to gain more insight into chronic sleep reduction in adolescents from different countries and to make cross-cultural comparisons, an English version of the questionnaire is highly needed for use in international sleep research and clinical practice. The aim of the present study is to develop an English version of the CSRQ and to assess the reliability and validity of the Dutch and English CSRQ questionnaire. We use the internal consistency of the questionnaires to assess reliabilities. In order to validate both questionnaires, we compare the factor structure of the Dutch CSRQ in a Dutch adolescent population to the factor structure of the English CSRQ in an English-speaking population. All Dutch data were independent of the data being used in the original study. Furthermore, we relate both CSRQ versions to subjective (survey, sleep diaries) and objective (actigraphy) school night sleep variables [e.g. TST, time in bed (TIB), sleep efficiency, sleep debt]. As it is known that chronically sleep-restricted individuals show significant declines in cognitive performance (van Dongen et al., 2003a,b), we also investigated the relationship between CSRQ and school performance.

3.2. Method
3.2.1. Participants
Participants were recruited from five high schools in and around Amsterdam and from five high schools in Adelaide and Outer Adelaide. All Dutch participants were attending years 3 or 4 of the highest high school level in the Netherlands. All Australian participants were
attending years 9, 10 or 11. Successful completion of year 12 in Australia and year 6 in the Netherlands offers students the opportunity to apply for competitive entry to university. The Dutch sample consisted of 166 adolescents [28% male; mean age = 15.2 ± 0.57 years (age range: 12.2–16.5 years)] and the English-speaking Australian sample of 236 adolescents [65% male, mean age = 15.5 ± 0.99 years (age range: 13.3–18.9 years)]. Eighty per cent of Australian parents were married or lived together, with 19% separated or divorced. Dutch families were comparable, with 76% of Dutch parents being married or living together, 19% being separated or divorced and the remaining parents having indicated ‘other’ (e.g. widowed).

3.2.2. Procedure
The study was conducted with the approval of the University of Amsterdam Review Board, the Social and Behavioural Research Ethics Committee of Flinders University and the Department of Education and Children’s Services (South Australia) Ethics Committee. Active informed consent was obtained from participating schools, parents and adolescents. Survey data on demographics and sleep were collected during school times. Sleep diary and actigraphy data were collected for the following five school nights (Sunday–Thursday night), as five nights of actigraphy are known to be a reliable sample to describe adolescents’ sleep patterns (Acebo et al., 1999). Afterwards, the CSRQ was administered as a paper version for the Australian adolescents and as an electronic version for the Dutch adolescents. Pen-and-paper administration has been found to be comparable to online administration with adolescents (Kraut et al., 2004).

3.2.3. Measures
3.2.3.1. Chronic Sleep Reduction Questionnaire
Chronic sleep reduction was measured using the CSRQ (Meijer, 2008). The 20-item CSRQ consists of four scales: ‘shortage of sleep’ (six items), ‘irritation’ (five items), ‘loss of energy’ (five items) and ‘sleepiness’ (four items) with reference to the previous 2 weeks. Each question has three ordinal response categories ranging from 1 to 3, with higher scores indicating more chronic sleep reduction. Cronbach’s α in a pre-adolescent population was 0.84 (Meijer, 2008). For the development of the English CSRQ version, the Dutch questionnaire was translated into English. Two independent people who were not involved in the study and unfamiliar with the CSRQ translated all items back into Dutch; differences were discussed and corrected by native English speakers. The English CSRQ version can be found in Appendix 1.
3.2.3.2. Sleep and outcome variables

3.2.3.2.1. Survey

3.2.3.2.1.1. Time in bed
TIB (survey) on school nights (Sunday–Thursday night) was measured by calculating the time between participants’ rise time and usual bedtime on school nights as reported in the survey. Answers were given in hours and minutes.

3.2.3.2.1.2. Sleep need
In order to assess sleep need, participants were asked in the survey to indicate how much sleep they would need to feel well rested during the day and function optimally. Answers were given in hours and minutes.

3.2.3.2.1.3. School performance
Participants were asked about the grades that they mainly received at school. Answers for the Dutch samples consisted of five categories ranging from ‘4 or lower’ (reflecting a clear ‘fail’ in the Netherlands) to ‘9/10’ (the highest grades that can be achieved in the Netherlands). The answers for the Australian sample consisted of eight categories ranging from ‘D’ and ‘E’ (reflecting a clear ‘fail’ in Australia) to ‘A’ (the highest grade that can be achieved in Australia). Differences in the number of answer categories result from different grading systems in the two countries. However, as both samples rated their grades on ordinal categories that represent an accurate picture of the Dutch and Australian grading system, we consider the two measurements as being comparable.

3.2.3.2.2. Sleep diaries

3.2.3.2.2.1. Time in bed
TIB (diary) on school nights (Sunday–Thursday nights) was measured by calculating the time between participants’ mean rise time on school days and mean bedtime on school nights as reported in the sleep diaries. Participants reported their exact rise time and bedtime in hours and minutes.

3.2.3.2.2.2. Sleep duration
Sleep duration (diary) on school nights (Sunday–Thursday nights) was assessed by calculating the time between participants’ mean sleep offset and mean sleep onset as reported in the sleep diaries. Participants reported their sleep onset time and sleep offset time in hours and minutes.
3.2.3.2.3. Sleep efficiency
Subjective sleep efficiency (diary), representing the percentage of sleep duration relative to the time spent in bed, was calculated by dividing sleep duration by TIB from the sleep diaries and multiplying this number by 100.

3.2.3.2.3. Actigraphy
Participants’ sleep activity was monitored using AW4 actiwatches in the Dutch sample (Cambridge Neurotechnology Ltd, Cambridge, UK) and MicroMini Motionloggers (Micro-Miniloggers; Ambulatory Monitoring Inc., Ardsley, New York, USA) in the Australian sample. Actigraphy involves use of a wristwatch-like portable device that can record movements over an extended period of time (e.g. a few weeks). Actigraphy is known to be a reliable and valid measure to study sleep in a natural environment (Kushida et al., 2001; Morgenthaler et al., 2007). Participants were instructed to wear the actigraph on their non-dominant wrist when they went to bed and remove it in the morning after they got up. The following sleep parameters were calculated from the data collected on school days: (i) sleep onset latency (SOL): time between individuals’ bedtime and sleep onset, (ii) sleep duration: time between sleep onset and sleep offset; (iii) total sleep time (TST): number of minutes that individuals actually slept, which is the time between sleep onset and sleep offset corrected for number of wake times during the sleep time; and (iv) sleep efficiency [defined as (TST/TIB) * 100]: percentage of uninterrupted night sleep. In both samples information about betimes (bedtime and rise time) from the sleep diaries was used to define the sleep scoring interval (Acebo et al., 1999). In the Dutch sample nocturnal activity data were logged at 1-min epochs and scored with the Actiwatch Sleep Analysis 7 (Cambridge Neurotechnology Ltd, Cambridge, UK) software. As recommended by the manufacturer, we used the medium sensitivity sleep algorithm. It has been shown that this algorithm corresponds well with polysomnographic estimates (Kushida et al., 2001). In the Australian sample nocturnal activity data were logged in 1-min epochs using zero crossing modes, with a sensitivity of 0.05 g and a frequency range of 2–3 Hz. Data were analyzed with the Action W2 software using the Sadeh algorithm. Sleep onset was defined as the first of three consecutive epochs of actigraphic sleep at the beginning of the scoring interval. Sleep offset was defined as the last of at least five consecutive epochs of actigraphic sleep at the end of the scoring interval.

3.2.3.2.4. Sleep debt
Sleep debt, defined as the difference between the amount of sleep someone would need and their reported sleep time, was calculated by subtracting individuals’ TST from their sleep need.
3.2.4. Statistical analysis

Multi-group confirmatory factor analysis (CFA) was used to investigate the factorial structure of the CSRQ, as well as the invariance of factor model parameters across groups. As the CSRQ items have three response options, we analysed polychoric correlations and thresholds. The assumption of fixed thresholds enables estimation of (relative) means, variances and covariances of latent continuous variables underlying the polychotomous items. As we cannot assume multivariate normality, we relied on the scaled Satorra–Bentler $\chi^2$ statistic of overall goodness-of-fit and the associated root mean square error of approximation (RMSEA). RMSEA values below 0.05 and 0.08 are considered to indicate ‘close’ and ‘satisfactory’ fit, and RMSEA values above 0.08 and 0.10 are considered ‘unsatisfactory’ and ‘bad’ (Browne and Cudeck, 1992). The factor analyses were conducted with Lisrel, a computer program for structural equation modeling (Jöreskog and Sörbom, 2006).

First, we investigated the factorial structural of the CSRQ items by testing whether the four-factor structure that was found previously (Meijer, 2008) applies to both the Dutch and the Australian sample. Secondly, we tested whether the factors have the same meaning across samples by testing across-group equality constraints on the factor loadings. Thirdly, we tested whether the CSRQ items are equally ‘difficult’ to Dutch and Australian adolescents by testing additional across-group equality constraints on the intercepts. If such an intercept constraint does not hold, this means that it is easier to respond ‘yes’ to an item in one language than in another even though the underlying sleep reduction is equivalent. In other words, with intercept constraints we test whether Dutch participants with the same degree of chronic sleep reductions as Australian participants would choose the same answer category of the item. Fourthly, we tested whether a single higher-order factor model fits the data of both samples and, fifthly, whether the higher-order factor loadings are the equivalent, which would indicate a single higher-order chronic sleep reduction factor for both language versions of the CSRQ. If (partial) invariance of factor loadings and intercepts holds, then we can additionally test equivalence of Dutch and Australian common factor means. Across-group equivalence of factor loadings and intercepts can be tested through $\chi^2$ difference tests. However, as calculating differences between the scaled Satorra–Bentler $\chi^2$ values is plagued by problems (Satorra and Bentler, 2010) that cannot be solved when analysing polychoric correlations in multi-group factor analysis, we relied upon the 90% confidence intervals (CI) of the RMSEA values instead.

In order to further validate the CSRQ, we calculated correlations of the total CSRQ score and its four subscales with the other sleep variables as well as with school performance. Reliabilities of both CSRQ versions and their subscales were calculated using
Cronbach’s α, a measure of internal consistency. Differences in sleep patterns between the two adolescent samples were tested using independent sample t-tests.

**Table 1. Means and standard deviations for both samples**

<table>
<thead>
<tr>
<th></th>
<th>Dutch (N=166)</th>
<th>Australian (N=236)</th>
<th>t-test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yrs)</td>
<td>15.15 (0.57)</td>
<td>15.52 (0.99)</td>
<td>4.29**</td>
</tr>
<tr>
<td>CSRQ</td>
<td>33.69 (6.71)</td>
<td>35.81 (6.97)</td>
<td>3.09**</td>
</tr>
<tr>
<td><strong>Survey (school nights)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sleep need (hr:min)</td>
<td>09:02 (00:59)</td>
<td>09:20 (00:58)</td>
<td>3.15**</td>
</tr>
<tr>
<td>Time in bed (hr:min)</td>
<td>08:29 (00:37)</td>
<td>08:35 (00:52)</td>
<td>1.44 n.s.</td>
</tr>
<tr>
<td><strong>Sleep diary (school nights)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time in bed (hr:min)</td>
<td>08:33 (00:38)</td>
<td>08:45 (00:46)</td>
<td>2.79**</td>
</tr>
<tr>
<td>Sleep duration (hr:min)</td>
<td>07:44 (00:46)</td>
<td>08:27 (00:46)</td>
<td>9.55***</td>
</tr>
<tr>
<td>Sleep efficiency</td>
<td>90.49 (3.01)</td>
<td>96.66 (3.01)</td>
<td>14.79***</td>
</tr>
<tr>
<td><strong>Actigraphy (school nights)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total sleep time (hr:min)</td>
<td>6:50 (00:33)</td>
<td>6:47 (00:50)</td>
<td>-0.57 n.s.</td>
</tr>
<tr>
<td>Sleep onset latency (hr:min)</td>
<td>00:23 (00:14)</td>
<td>00:23 (00:01)</td>
<td>0.48 n.s.</td>
</tr>
<tr>
<td>Sleep duration (hr:min)</td>
<td>08:04 (00:36)</td>
<td>08:03 (00:43)</td>
<td>-0.22 n.s.</td>
</tr>
<tr>
<td>Sleep efficiency</td>
<td>80.04 (6.28)</td>
<td>77.79 (9.57)</td>
<td>-2.66**</td>
</tr>
<tr>
<td>Sleep debt (hr:min)</td>
<td>02:12 (01:05)</td>
<td>02:33 (01:11)</td>
<td>3.13**</td>
</tr>
</tbody>
</table>

**Note.** CSRQ = Chronic Sleep Reduction Questionnaire

¹ Due to two items having different measurement properties, the absolute CSRQ scores should not be compared across samples and different norm scores for the two CSRQ versions should be developed (see Discussion).

Time in bed (survey) = Time between bed time and rise time as reported in the survey
Time in bed (diary) = Time between bed time and rise time as reported in the sleep diary
Sleep duration (diary) = Time between sleep onset and sleep offset as reported in the sleep diary
Sleep efficiency (diary) = Sleep duration (diary)/Time in bed (diary) *100
Total sleep time = Minutes of actually obtained sleep
Sleep duration (actigraphy) = Time between sleep onset and sleep offset measured with actigraphy
Sleep efficiency (actigraphy) = Total sleep time/Time in bed (diary) *100
Sleep debt = Total sleep time – sleep need

### 3.3. Results

#### 3.3.1. Descriptive statistics: sleep variables

Means and standard deviations (SD) for both samples’ sleep variables and CSRQ scores are given in Table 1. Survey data show that the two samples did not differ significantly in their time spent in bed. However, Australian adolescents reported a higher sleep need than Dutch adolescents. Sleep diary data showed significant differences on sleep duration, TIB and sleep efficiency. TST, SOL and sleep duration from the objective sleep measures were of comparable size in both samples. Australian adolescents had lower sleep efficiencies and
more sleep debt than Dutch adolescents; however, these differences can be contributed to differences in TIB as reported in the sleep diaries and different sleep needs as reported in the survey. Furthermore, Australian adolescents reported significantly more chronic sleep reduction than Dutch adolescents.

3.3.2. Factor structure of the CSRQ

The factor model fit for the Dutch and the English CSRQ version was satisfactory for the Dutch ($\chi^2 = 166.75, p = 0.00; \text{RMSEA} = 0.062; 90\% \text{ CI } 0.048; 0.075$) and good for the English version ($\chi^2 = 256.56, p = 0.00; \text{RMSEA} = 0.049; 90\% \text{ CI } 0.037; 0.060$), allowing us to proceed with the subsequent steps. Table 2 gives the $\chi^2$ and RMSEA values for all models.

**Table 2. Goodness of fit statistics**

<table>
<thead>
<tr>
<th>Model</th>
<th>df</th>
<th>$\chi^2$</th>
<th>$p$</th>
<th>RMSEA</th>
<th>90% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model 1</td>
<td>328</td>
<td>502.44</td>
<td>0.00</td>
<td>0.052</td>
<td>0.042; 0.060</td>
</tr>
<tr>
<td>Model 2</td>
<td>344</td>
<td>535.21</td>
<td>0.00</td>
<td>0.053</td>
<td>0.044; 0.061</td>
</tr>
<tr>
<td>Model 3</td>
<td>360</td>
<td>816.43</td>
<td>0.00</td>
<td>0.080</td>
<td>0.072; 0.087</td>
</tr>
<tr>
<td>Model 4</td>
<td>358</td>
<td>620.44</td>
<td>0.00</td>
<td>0.061</td>
<td>0.052; 0.068</td>
</tr>
<tr>
<td>Model 5</td>
<td>362</td>
<td>627.62</td>
<td>0.00</td>
<td>0.061</td>
<td>0.052; 0.068</td>
</tr>
<tr>
<td>Model 6</td>
<td>365</td>
<td>631.40</td>
<td>0.00</td>
<td>0.060</td>
<td>0.052; 0.068</td>
</tr>
</tbody>
</table>

*Note. Model 1: First order CFA; Multi-group analysis without equality constraints
Model 2: First order CFA; Multi-group analysis with equality constraints on the factor loadings
Model 3: First order CFA; Multi-group analysis with equality constraints on the factor loadings and intercepts
Model 4: First order CFA; Multi-group analysis with equality constraints on the factor loadings and intercepts (item 6 and 9 freed)
Model 5: Second order CFA; Multi-group analysis with equality constraints on the factor loadings and intercepts (item 6 and 9 freed)
Model 6: Second order CFA; Multi-group analysis with equality constraints on the factor loadings, intercepts (item 6 and 9 freed) and factor loadings of the latent factor;

$\chi^2 = $ Satorra-Bentler Scaled Chi-Square; df = degrees of freedom; RMSEA = Root Mean Square Error of Approximation; 90% CI = 90% Confidence interval

First, our results show the same overall structure for both CSRQ versions (model 1). When factor loadings were constrained to be equal across the two groups (model 2), no significant changes in model fit occurred, indicating that the four common factors have the same interpretation in the two language versions. However, the hypothesis of equivalent intercepts did not hold across samples (model 3). Stepwise modification of the model, allowing varying intercepts of item 6 (I oversleep in the morning) and item 9 (Do other people think that you react angrily when they ask you for something or say something to you?), yielded a close model fit (model 4). The RMSEA value of this model still lies within the CI of the RMSEA for model 2. The higher intercepts for items 6 and 9 in the English version indicated that, given
equivalent chronic sleep reduction, Australian participants were more likely to score high on items 6 and 9 than were Dutch participants. Parameter estimates and common factor correlations of model 4 are given in Figure 1. With at least partial invariance of factor loadings and intercepts established, we can now compare the common factor means of each factor for the Australian and the Dutch groups. The results show that the Australian sample had higher scores for the subscales ‘irritation’, ‘loss of energy’ and ‘sleepiness’ than the Dutch sample; however, the opposite was true for ‘shortness of sleep’ (see Figure 1). A high correlation of 0.83 and 0.91 between the factors ‘sleepiness’ and ‘loss of energy’ was observed for the Dutch and the Australian sample, respectively, suggesting that the two factors represent a single construct. However, a three-factor model that combines the two factors did not fit as well as the four-factor model ($\chi^2 = 654.20, p = 0.00$; RMSEA = 0.063; 90% CI 0.055; 0.070).

Inspired by the original work of the CSRQ (Meijer, 2008), we also investigated whether or not the four latent factors (‘irritation’, ‘shortness of sleep’, ‘loss of energy’ and ‘sleepiness’) can be considered as measurements of a single higher-order factor, namely chronic sleep reduction. Both model 5 and model 6 (with additional equality constraints on second-order factor loadings) resulted in satisfactory model fit (see Table 2). We conclude that the higher-order factor chronic sleep reduction seems to be a good representation of the four latent variables for both groups.

To summarise, our results show that the CSRQ has the same structure in the two samples, behaves comparably and that the majority of items can be interpreted similarly. However, Australian participants were more likely to score highly on items 6 and 9 than Dutch participants. Furthermore, we showed that the four latent factors can be represented by a higher-order factor, namely chronic sleep reduction.

### 3.3.3. CSRQ scales

As a measure of reliability (internal consistency) that resulted from the common factor analyses, Cronbach’s $\alpha$s were calculated for the four scales. Cronbach’s $\alpha$ was satisfactory for all scales for both groups (Dutch sample: CSRQ: $\alpha = 0.85$; ‘shortness of sleep’: $\alpha = 0.60$; ‘irritation’: $\alpha = 0.66$; ‘loss of energy’: $\alpha = 0.76$; ‘sleepiness’: $\alpha = 0.74$; Australian sample: CSRQ: $\alpha = 0.87$; ‘shortness of sleep’: $\alpha = 0.68$; ‘irritation’: $\alpha = 0.65$; ‘loss of energy’: $\alpha = 0.71$; ‘sleepiness’: $\alpha = 0.80$).
Note. NL = Dutch sample; OZ = Australian sample

For the Australian sample we obtained the following common factor means (Dutch sample was used as reference group; fixed at zero): Irritation: .44; Loss of energy: .22; Shortness of sleep: -.26; Sleepiness: .33

Figure 1. Parameter estimates for the common factor model: Factor loadings, intercepts and common factor correlations.

3.3.4. The relationship of the CSRQ with sleep and school performance

Inspection of the distribution of scale scores showed that some sleep variables and school performance were not distributed normally. We transformed these data using different transformation algorithms (e.g. log transformations, square root transformations). As correlations for the transformed sleep scores were very similar to those of the original scores, we used the original scores for further analyses. Concerning school performance, we used the data that contained the logarithmic values of the original school performance variable. Table 3 reports correlations between the total CSRQ, its four different subscales, sleep variables and school performance for the Dutch and Australian samples, respectively.
Table 3. Correlations between the CSRQ, the CSRQ subscales, sleep variables and school performance

<table>
<thead>
<tr>
<th></th>
<th>Australian sample (N=236)</th>
<th>Dutch sample (N = 166)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CSRQ</td>
<td>Intimacy</td>
</tr>
<tr>
<td><strong>School performance</strong></td>
<td>-0.18 (p ≤ 0.01)</td>
<td>-0.04 (p = 0.56)</td>
</tr>
<tr>
<td><strong>Sleep need</strong></td>
<td>0.14 (p = 0.03)</td>
<td>0.03 (p = 0.70)</td>
</tr>
<tr>
<td><strong>Time in bed (survey)</strong></td>
<td>-0.29 (p ≤ 0.001)</td>
<td>-0.16 (p = 0.01)</td>
</tr>
<tr>
<td><strong>Sleep diary</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Time in bed (diary)</strong></td>
<td>-0.14 (p = 0.04)</td>
<td>-0.07 (p = 0.28)</td>
</tr>
<tr>
<td><strong>Sleep duration (diary)</strong></td>
<td>-0.20 (p ≤ 0.01)</td>
<td>-0.08 (p = 0.24)</td>
</tr>
<tr>
<td><strong>Sleep efficiency (diary)</strong></td>
<td>-0.21 (p ≤ 0.01)</td>
<td>-0.03 (p = 0.60)</td>
</tr>
<tr>
<td><strong>Actigraphy</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total sleep time (actigraphy)</strong></td>
<td>-0.09 (p = 0.17)</td>
<td>-0.13 (p = 0.06)</td>
</tr>
<tr>
<td><strong>Sleep onset latency (actigraphy)</strong></td>
<td>0.34 (p ≤ 0.001)</td>
<td>0.12 (p = 0.07)</td>
</tr>
<tr>
<td><strong>Sleep duration (actigraphy)</strong></td>
<td>-0.18 (p ≤ 0.01)</td>
<td>-0.12 (p = 0.06)</td>
</tr>
<tr>
<td><strong>Sleep efficiency (actigraphy)</strong></td>
<td>0.01 (p = 0.92)</td>
<td>-0.07 (p = 0.26)</td>
</tr>
<tr>
<td><strong>Sleep debt (actigraphy)</strong></td>
<td>0.18 (p ≤ 0.01)</td>
<td>0.11 (p = 0.09)</td>
</tr>
</tbody>
</table>

Note. Time in bed (survey) = Time between bed time and rise time as reported in the survey
Time in bed (diary) = Time between bed time and rise time as reported in the sleep diary
Sleep duration (diary) = Time between sleep onset and sleep offset as reported in the sleep diary
Sleep efficiency (diary) = Sleep duration (diary)/Time in bed (diary) *100
Total sleep time = Minutes of actually obtained sleep
Sleep duration (actigraphy) = Time between sleep onset and sleep offset measured with actigraphy
Sleep efficiency (actigraphy) = Total sleep time/Time in bed (diary) *100
Sleep debt = Total sleep time – sleep need

In both samples the total CSRQ was correlated with most sleep variables in the expected directions. High chronic sleep reduction was related to less time spent in bed and to a higher sleep need as reported in the survey. Furthermore, the CSRQ was associated significantly
with shorter sleep durations and lower sleep efficiencies from the sleep diaries. TIB from the sleep diaries was the only variable from the diaries that was not related to chronic sleep reduction in the Dutch sample. Although this correlation was significant in the Australian sample, correlation coefficients were of comparable size (Dutch sample $r = -0.12$ and Australian sample $r = -0.14$). Concerning the actigraphy measurements, individuals with high chronic sleep reduction had significantly longer SOLs, shorter sleep durations (time between sleep onset and sleep offset) and more sleep debt. Interestingly, the CSRQ was not related to objectively measured TST and sleep efficiency. As hypothesized, chronic sleep reduction was related strongly to school performance in both samples, with participants scoring high on the CSRQ reporting worse school performance than participants scoring low on the CSRQ. Except for chronic sleep reduction, we only found significant correlations with school performance for SOLs in both samples (Dutch: $r = -0.18$, $p < 0.05$; OZ: $r = -0.15$, $p < 0.05$) and for sleep debt in the Dutch sample ($r = -0.18$; $p < 0.05$). No significant correlations between school performance and the other sleep variables were found (all $p$s $> 0.05$).

We also calculated the correlations between the CSRQ subscales with the other sleep variables and school performance. Differences of correlations across samples turned out to be insignificant ($\chi^2 = 47.02$; df = 44; $p = 0.35$), indicating equivalence across the Dutch and the Australian sample. In both samples especially the subscale ‘shortness of sleep’ showed significant correlations with most other sleep variables, whereas the subscale ‘irritation’ was less associated with sleep as measured by the survey, sleep diaries and actigraphy (see Table 3).

### 3.4. Discussion

The Dutch CSRQ is a questionnaire that measures chronic sleep reduction by assessing symptoms of chronic insufficient and/or poor sleep. In this sense, it accounts for individual differences in sleep need and sleep debt. The questionnaire represents an easy and cost-effective way to measure chronic sleep reduction in adolescents. However, an English version of the CSRQ is highly needed in order to compare study results and to assess chronic sleep reduction in the clinical setting. Therefore, the present study developed an English version of the CSRQ and assessed the reliabilities and validity of both CSRQ versions.

The same overall structure of the questionnaire was found for both samples, and it was shown that both CSRQ versions consist of the same common factors. Nevertheless, although highly correlated, the four-factor model fitted better than models with fewer factors, indicating that the four CSRQ factors measure different aspects of chronic sleep reduction. Based on our study, we can conclude that the English CSRQ version measures the same
constructs as the original Dutch CSRQ version, supporting the validity for both the original measurement and the English version. Cronbach’s αs were satisfactory for both CSRQ versions, being comparable to reliabilities reported by the original study (Meijer, 2008). These results indicate satisfactory internal consistency of both CSRQ versions.

Although we found the same overall structure of the CSRQ in both samples, two items differed in ‘difficulty’, meaning that, given an equivalent degree of chronic sleep reduction, Australian participants were more likely to score higher on item 6 (I oversleep in the morning) and item 9 (Do other people think that you react angrily when they ask you for something or say something to you?) than Dutch participants. The difference in item 6 may be due to language differences, as ‘angrily’ may, for instance, have a weaker loading than ‘boos’ (the Dutch equivalent). In combination with the result that Australian adolescents had higher CSRQ scores than Dutch adolescents, this finding indicates that absolute CSRQ scores of the two questionnaires should not be compared directly. In order to make such cross-cultural comparisons, different norm scores (including clinical cut-off scores) for different populations are needed and should be developed in future studies. However, at present the two CSRQ versions can be used for research purposes when comparing relationships with other outcome variables in different samples.

We attempted to administer the CSRQ in two comparable samples; however, adolescents differed on important characteristics such as age and gender that are known to influence sleep patterns as well as daytime functioning. Despite these differences between the two samples, the CSRQ behaved comparably in both groups, again supporting the validity of the questionnaire. Concerning differences between samples with respect to the CSRQ, the common factor means can be seen as a more valid comparison of the sample than total CSRQ score, showing that Australian adolescents scored lower on the subscale ‘shortness of sleep’ and higher on the other three subscales than Dutch adolescents.

We validated the CSRQ against subjective (survey, sleep diary) and objective (actigraphy) sleep variables and additionally related it to school performance as an indication for cognitive and daily functioning. With one exception in the Dutch sample (TIB from the sleep diaries), the CSRQ was related significantly to the other subjective sleep variables, meaning that adolescents with higher CSRQ scores experienced worse sleep efficiency, had shorter sleep durations and reported spending less time in bed. Objectively measured SOL and sleep duration (time between sleep onset and sleep offset) were related significantly to the CSRQ in both groups, meaning that individuals with longer SOLs or shorter sleep durations reported more chronic sleep reduction than adolescents with shorter SOLs or longer sleep durations. Furthermore, chronic sleep reduction and sleep debt were correlated highly in both samples. These findings support our expectation and strengthen the validity of
the CSRQ, especially because similar relationships were found in the two independent samples.

The positive relationship between SOL and chronic sleep reduction in both samples is of high interest as it could be argued that chronic sleep reduction should lead to shorter SOL because sleep reduction and sleep debt may cause immediate sleep onset after going to bed. However, chronic sleep reduction may also be present in adolescents suffering from (mild) insomnia and delayed sleep phase syndrome, which are prevalent worldwide occurring problems in this age group (Gradisar et al., 2011). Long SOLs are common characteristics in these sleep disorders and may explain the result of the present study. As the limited research on chronic sleep reduction as measured by a specific chronic sleep reduction tool, does not enable us to compare our findings with other studies that support or contradict our results, future studies should try to gain more insight into this interesting association.

In order to gain more insight into the different relationships of the four different CSRQ subscales, we also investigated their relationships with the sleep variables and school performance separately. The relationships turned out to be equivalent across samples. In both groups the subscale ‘shortness of sleep’ showed significant correlations with most of the other sleep variables, whereas the subscale ‘irritation’ was less associated with sleep as measured by the survey, sleep diaries and actigraphy. Conversely, this finding highlights the importance of including different symptoms of chronic sleep reduction. As individual differences manifest in the relation of sleep debt to sleep need, they may also play a role in the symptoms of chronic sleep reduction and the way in which these symptoms are perceived. Based on the high correlations that we found between the subscales, one can speculate that the effects of sleep (e.g. sleep duration) on emotional and/or behavioural symptoms (e.g. irritation) may occur rather indirectly via the other chronic sleep reduction symptoms (e.g. the perception of not getting enough sleep). Conversely, the somewhat low correlations of the ‘irritation’ subscale with the other sleep variables and its possible overlap with internalizing and externalizing problems raises the question of whether or not this subscale represents a valid symptom that should be used when measuring chronic sleep reduction in the future. Although it was shown that adolescents’ irritability is related to sleep problems (e.g. Dahl, 1999) and that the possible overlap with internalizing and/or externalizing problems refers to a general bidirectional problem (Gregory and Sadeh, 2012), it can be argued that irritability is not a universal symptom of chronic sleep reduction that can be observed in all adolescents. Future research needs to determine the extent to which irritation is a response to chronic sleep reduction for all adolescents and, if not, what factors predict irritation in response to sleep loss. The CSRQ includes symptoms of insufficient
and/or poor sleep, but the present study does not include a measure of subjective sleep quality (discussed below in more detail). Therefore, additional validation of this subscale is planned in further research. Based on the present data and the above described theoretical evidence, the subscale ‘irritation’ should be interpreted carefully, especially when examining relations between chronic sleep reduction and adjustment.

School performance was related significantly to chronic sleep reduction in both samples, supporting the idea that chronic sleep reduction appears to be a sensitive construct to detect the effects of insufficient and/or poor sleep on cognitive and daily functioning. This may be due to the fact that chronic sleep reduction considers sleep debt and individuals’ sleep need as well as aspects of subjective sleep quality. Subjective sleep quality refers to initiating and maintaining sleep as well as to the subjective indices of sleep, such as how well-rested one feels upon awakening and satisfaction with sleep (Pilcher et al., 1997). It was shown that subjective sleep quality is related strongly to chronic sleep reduction and its effects on outcome variables, such as emotional and behavioural problems, school performance and functioning at school (Meijer, 2008; Meijer et al., 2010). Although we did not include a direct measure of subjective sleep quality, the finding that except chronic sleep reduction SOL, measuring initiating sleep, was the only sleep variable that was related to school performance in both samples, supports the idea that subjective sleep quality is an important aspect of chronic sleep reduction which influences daily functioning. Our results confirm the findings from a recent meta-analysis showing that the association between school performance and sleep quality is stronger than the relationship between sleep duration and school performance (Dewald et al., 2010). Based on our results, we can conclude that subjective sleep quality or chronic sleep reduction may be better indicators of the effects of sleep problems on adolescents’ daytime functioning.

The CSRQ refers to a time-frame of the previous 2 weeks and was validated against five school nights of sleep. In adults, chronic sleep restriction over 2 weeks resulted in subjective sleepiness and impaired neurobehavioural functioning (van Dongen et al., 2003a,b). To date, it is not clear how much time it takes for an adolescent to show symptoms of chronic sleep reduction, and needs to be investigated in future studies. Conversely, it is also not yet known how much time with sufficient and/or good sleep it takes to recover from symptoms of chronic sleep reduction. Results from a study in adults show that after chronic mild to moderate sleep restriction (5 or 7 h TIB during 7 days), 3 days of recovery sleep (8 h TIB) did not restore performance to baseline levels (Belenky et al., 2003), suggesting that chronic sleep restriction might have enduring effects over a longer time. However, more research is needed to assess whether longer time-frames of the CSRQ (e.g. 1 month, 6
months) provide differential responses and to determine whether the assumption holds that five school nights provide a satisfactory representation of adolescents’ sleep.

It has been reported that adolescents need approximately 9 h sleep per night. Carskadon and Acebo (2002) showed in one of their famous studies that the ‘ideal’ amount of sleep would be 9.2 h of sleep. Interestingly, adolescents in both samples report a mean sleep need of approximately 9 h, showing that individuals in this study were fairly accurate on their self-perception of required sleep.

A few limitations of the present study need to be addressed. First, the present study assessed the relationship of chronic sleep reduction with sleep variables reflecting TST; however, no measurement of self-reported sleep quality was included. As discussed above, subjectively measured sleep quality may play an important role in chronic sleep reduction and its effects on adolescents’ daytime functioning. Secondly, relationships between the CSRQ and other self-reported sleep variables as well as school performance may be inflated because of mono-informant bias. Replicating these relationships using objective measures for school performance is therefore recommended. Thirdly, assessing grades for different subjects separately rather than asking for overall grades could provide more insight into how academic abilities are affected differentially by chronic sleep reduction. Based on empirical evidence that demonstrated an association between sleep and the consolidation of cognitive performance and memory, being required for abstract reasoning, goal directed behaviour and creative processing (Curcio et al., 2006; Walker et al., 2002), it can be questioned whether or not some cognitive domains may be more sensitive to sleep deficits than others. Fourthly, the usage of different actigraphy devices and softwares constitutes a limitation. To date, the two types of actigraphy and softwares have not been compared with each other in one study. However, our results show that the two samples did not differ significantly on TST, sleep duration and SOL. Furthermore, correlations between the CSRQ scales and sleep variables were equivalent across samples, although methodological differences in the two groups should be kept in mind and future cross-cultural studies should try to use the same devices and softwares to compare sleep patterns of different groups.

The present study can conclude that the English CSRQ version represents an important step in the assessment of chronic sleep reduction in adolescents. Due to its practical applicability, it can be used for upcoming research, educational and clinical purposes. While it was shown that the English version is a reliable and valid assessment tool, future research should concentrate on cross-cultural comparisons with the CSRQ and its norm scores. Such research is important as it can provide more insight into possible differences concerning social and environmental factors between countries. The development of norm scores should also include different clinical group that are diagnosed
with sleep disorders (e.g. insomnia, delayed sleep phase syndrome) or other clinical disorders (e.g. depression). Comparing these groups could result in clinical cut-off scores that may be useful in the application of treatments. Future studies should also focus on the relationship and possible overlap between different symptoms of chronic sleep reduction and emotional and/or behavioural problems. Gaining more insight into these relationships may also contribute to our knowledge on the complex interplay between sleep and adjustment problems (e.g. depression, aggressive behaviour). More research addressing the validity of the ‘irritation’ subscales should be conducted in future. Such validation studies should focus particularly on subjective sleep quality and sleep over a longer time-period. Furthermore, studies including additional daytime functioning measurements tapping into other domains, such as psychological wellbeing or quality of life, would improve our knowledge and understanding of the role of chronic sleep reduction in adolescents.

To summarise, as chronic sleep reduction focuses on symptoms of insufficient sleep rather than TST, this measurement is a more promising indicator of the effects of sleep problems on adolescents’ daily functioning than sleep duration.
3.5. References


van Dongen, H.P.A., Maislin, G., Mullington, J.M. and Dinges, D.F. The cumulative cost of additional wakefulness: dose–response effects on neurobehavioral functions and
sleep physiology from chronic sleep restriction and total sleep deprivation. Sleep, 2003a, 26: 117–126.


3.6. APPENDIX 1: English CSRQ version

1. Do you have trouble getting up in the morning?  
☐ no  ☐ sometimes  ☐ yes

2. Do you feel well rested at school?*  
☐ no  ☐ sometimes  ☐ yes

3. Do you feel sleepy during the day?  
☐ no  ☐ sometimes  ☐ yes

4. Do you often yawn throughout the day?  
☐ no  ☐ sometimes  ☐ yes

5. Are you immediately wide awake when you wake up?*  
☐ no  ☐ sometimes  ☐ yes

6. I oversleep in the morning (e.g., continuing to sleep even though I need to get up)  
☐ never  ☐ once in a while  ☐ often.

7. At noon I feel as energetic as in the morning.  
☐ this is true for me  ☐ I feel less alert at noon  ☐ I feel alot less alert at noon

8. When I am at school for a while I have trouble keeping my eyes open.  
☐ no  ☐ sometime  ☐ yes

9. Do other people think that you react angrily when they ask you for something or say something to you?  
☐ no  ☐ sometimes  ☐ yes

10. When I do not get enough sleep it is more likely that I start an argument.  
☐ no, this is not true for me  
☐ yes, that is true for me once in a while  
☐ yes, that is often true for me.

11. Do you have enough energy during the day to do everything?*  
☐ no  ☐ sometimes  ☐ yes

12. I am active during the day.  
☐ agree  ☐ partly agree  ☐ do not agree

13. I have to struggle to stay awake in class.  
☐ never  ☐ once in a while  ☐ often
14. Do other people say that you seem annoyed?
   □ no               □ sometimes               □ yes

15. I don’t feel like going to school because I feel too tired.
   □ this never happens
   □ this happens once a week
   □ this happens more often than twice a week

16. I feel very alert at school.
   □ agree               □ partly agree             □ do not agree

17. I am a person who does not get enough sleep.*
   □ agree               □ partly agree             □ do not agree

18. I would like to sleep longer.
   □ no, I sleep exactly enough.
   □ no, I would like to sleep shorter.
   □ yes, I would like to sleep longer.

19. Others think that I am easily irritated.
   □ this is not true for me □ this is partly true for me □ this is true for me

20. Do you think that you behave unkindly towards your friends or parents without a reason?
   □ no               □ sometimes               □ yes

Coding:
All items are coded with 1, 2, or 3 with higher scores indicating more chronic sleep reduction.
The total chronic sleep reduction score is calculated by adding the scores of all items.

*Items have to be reverse coded

Subscales:
- shortness of sleep: 1, 5, 6, 7, 17, 18
- irritation: 9, 10, 14, 19, 20
- loss of energy: 2, 11, 12, 15, 16
- sleepiness: 3, 4, 8, 13