

**AUTOMATIC SCSB ANALYSIS OF MOTOR AND AUTONOMIC
NERVOUS ACTIVITY IN INFANTS COMPARED TO
EEG-BASED SLEEP STAGES**

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Syksy 2002

Automatic scsb analysis of motor and autonomic nervous activity in infants compared to EEG-based sleep stages

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Pro Gradu Thesis

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September 2002

22 pages

Abstract

The aim of this study was to examine, whether the software BR99 developed for analysing the static charge sensitive bed (SCSB) data is accurate for infants' sleep stage scoring. Periods of sleep, varying from 24 to 74 minutes, were chosen from 15 new-born infants. The polysomnographic recordings included EEG C4, EMG and EOG from both eyes. Respiration and motility were recorded by the SCSB system. A clinical neurophysiologist scored the sleep stages in 30-second epochs using the traditional polysomnographic variables (EEG, EMG, EOG and respiration), and the software BR99 did the same by using the amount of small movements, variation of respiration frequency and variation of respiration amplitude and calculating a variation score from these. The agreement percent of these two methods was 59 for the whole data. After taking a look at the epochs of greatest disagreement some explanations were found. Naturally the SCSB emphasises motility and variability of autonomic activities whereas the traditional sleep stage scoring based on polysomnography relies more on EEG and EOG, and when these two are controversial, disagreement occurs. Another problems were due to the BR99 software. It seems to get confused when calculating the variation score especially for some really active epochs. Some of those were classified quiet sleep despite great activity and variation.

Second problem of the BR99 is that it does the sleep stage classification in 3-minute epochs which clearly is a too long period. As a conclusion, this software is not accurate enough for sleep studies in infants and needs further development, but it also looks promising, since similar studies have given good results in adults. Altogether, this version cannot reach all the special phenomenas of infants' sleep which differ from adults.

Key words: sleep, newborns, static charge sensitive bed (SCSB), polysomnography, movements, respiration

Vauvojen motorisen ja autonomisen hermoston aktiivisuuden automaattinen scsb-analyysi verrattuna EEG-pohjaiseen univaiheluokitteluun

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Syyskuu 2002

22 sivua

Tiivistelmä

Tutkimuksen tarkoituksena oli selvittää static charge sensitive bed (SCSB)-unipatjan rekisteröintien analysointiin kehitetyn BR99-ohjelmiston käyttökelpoisuutta vauvojen univaiheiden luokituksessa. Tutkimukseen valittiin 24-74 minuutin pituisia unijaksoja 15 vastasyntyneeltä, joilta rekisteröitiin EEG C4, EMG, EOG molemmista silmistä sekä unipatjan avulla liikkeet ja hengitys. Kliininen neurofysiologi teki univaiheluokituksen 30 sekunnin jaksoissa EEG:n, EMG:n, EOG:n ja hengityksen säännöllisyyden perusteella, ja BR99-ohjelmistolla tehtiin luokitus pienten liikkeiden, hengityksen frekvenssivaihteluiden sekä hengityksen amplitudivaihteluiden perusteella laskemalla näistä yhteisvariaatiosumma. Yhtenevyysprosentti näiden kahden menetelmän välillä oli 59 koko aineistolle. Jaksoja, joissa erimielisyys oli selvintä, tarkasteltiin laadullisesti, ja löydettiin joitakin selityksiä ristiriidoille. Osa erimielisyydestä johtui luonnollisesti kahden eri menetelmän tavoista painottaen eri asioita luokituksessa. Perinteinen univaiheluokitus keskittyy EEG:hen ja silmänliikkeisiin, kun taas SCSB-pohjainen analyysi korostaa motoriikkaa ja autonomisen aktiiviteetin vaihtelevuutta. Osa ongelmista liittyi BR99-ohjelmistoon. Siinä ilmeni selviä vaikeuksia laskea oikein variaatiosumma etenkin joillekin hyvin aktiivisille jaksoille, jolloin ne luokiteltiin

toisinaan hiljaiseksi uneksi. Toisena ohjelmiston ongelmana on tapa tehdä luokitus kolmen minuutin jaksoissa, mikä on selvästi liian pitkä jakso univaiheiden luokittamiselle. Johtopäätöksenä voidaan todeta, että tällaisenaan ohjelma ei ole tarpeeksi tarkka vauvojen unitutkimukseen ja tarvitsee edelleen kehittämistä, mutta ohjelmisto on kuitenkin lupaava sillä se on osoittautunut luotettavaksi aikuisten unitutkimuksessa. Tällaisenaan se ei kuitenkaan tavoita vauvojen nukkumiseen liittyviä spesifejä, aikuisten nukkumisesta poikkeavia ominaisuuksia.

Avainsanat: vastasyntyneet, uni, SCSB-unipatja, polysomnografia, liikkuminen, hengitys

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1. Introduction

Sleeping is not only spending a third of your life unconscious. Sleep has several functions, some still not fully understood. The time spent asleep is not the same all the time, since sleep includes different stages and each of them have their own characteristic behaviour. Objectively variation of motility, and central and autonomic nervous system's activity can be observed and subjectively we have dreams at certain stages of sleep. Different amounts of activity and certain kinds of electroencephalogram (EEG) can be registered in different stages of sleep. The traditional polysomnographic sleep recordings are done with EEG, electromyogram (EMG), electro-oculograms (EOG) and respiration (Anders, Emde & Parmelee 1971; Rechtschaffen & Kales 1968). These studies are nevertheless expensive and often uncomfortable to the subject, who is chained in bed by several electrodes. That's why a static charge sensitive bed (SCSB) –system has been studied. It is easy and inexpensive to use and comfortable for the subject, who can sleep and move freely without any attached electrodes (Alihanka & Vaahtoranta 1979). The mechanism will be described more in following chapters. The aim of this study is to examine the use of an automatic software BR99 in sleep stage scoring in new-born infants, a software developed specially for the analysis of SCSB recordings.

A sleep-wake cycle can be observed in a fetus 30-34 weeks old, and from then on it develops towards adult-like sleep. 3-4-year-old children have approximately the same phases and the same length of sleep cycle as adults (Falck 1983). In a new-born, a sleep cycle is about 40-70 minutes long (Falck 1983; Hoppenbrouwers, Hodgman, Harper & Sterman 1982; Hoppenbrouwers 1987; Stern, Parmelee, Akiyama, Schultz & Wenner 1969), and three sleep stages can be differentiated: active sleep, quiet sleep and intermediate sleep. Active sleep can't be regarded as the same as adult rapid eye movement (REM)-sleep, and in quiet sleep the four different phases which are distinguishable in adult sleep can't yet be differentiated (Anders & Weinstein 1972; Falck 1983; Hoppenbrouwers 1987). By three months of age, the EEG patterns of quiet sleep can begin to be subclassified into different non-rapid eye movement (NREM) stages (Anders & Weinstein 1972). The percentages of different sleep stages differ markedly from adult sleep. In infant

about 50% of sleep is active sleep, nearly 40% is quiet sleep and about 10% is intermediate sleep. As the infant develops, the amount of active sleep decreases and the other two stages increase their partial percentages (Coons 1987; Hoppenbrouwers et al 1982; Hoppenbrouwers 1988; Falck 1983), and reach the normal adult percentages of 20% REM and 80% NREM in late childhood (Anders & Weinstein 1972). When falling asleep, new-borns often go straight to active sleep, and this phenomena changes within the first months of life so that the sleep begins with non-REM sleep as in adults (Coons 1987; Hoppenbrouwers 1988).

Sleep stages can be differentiated by following several variables in the human body. Already in 50's it was noticed that variations in eye movements and body motility, including breathing, are related to different stages of sleep (Aserinsky & Kleitman 1953 and 1955; Dement & Kleitman 1957) and at that time the development of EEG made it possible to study the human brain activities more accurately. Already at that time it was also noticed that certain types of bodily movements in sleep are related to different EEG based sleep stages (Dement & Kleitman 1957).

Several studies have concluded that active sleep, and REM in grown-ups, is characterised by irregular breathing, and in quiet sleep the breathing is regular (Alihanka, Toivonen, Hasan & Vaahtoranta 1983; Hathorn 1974; Kirjavainen, Cooper, Polo & Sullivan 1996a; Parmelee, Wenner & Schultz 1964; Remmers, Bartlett & Putnam 1976; Snyder, Hobson, Morrison & Goldfrank 1964). The difference in respiratory rate and minute ventilation is significant between active and quiet sleep (Curzi-Dascalova, Gaudebaut & Dreyfus-Brisac 1981; Finer, Abroms & Tausch 1976; Hathorn 1974). Also the respiratory movements are faster in active sleep (Kirjavainen et al 1996b). Regularity of breathing is one of the basic variables in classifying sleep stages in infants (Anders et al 1971). Respiratory rate in quiet sleep diminishes as the infant gets older (Dittrichova 1969). Active sleep can be reliably differentiated from quiet sleep in infants according to respiratory and cardiological variables (Haddad, Jeng, Lai & Mellins 1987).

Body activity is also different in different sleep stages. In active sleep there are significantly more movements than in quiet sleep (S2-S4 in grown-ups), and sleep stages can be differentiated according to the amount of movements (Wilde-Frenz & Schulz 1983), at least roughly enough to differentiate active sleep from

quiet sleep both in infants and in grown-ups (Jansen & Shankar 1993; Sadeh, Acebo, Seifer, Aytur & Carskadon 1995). Particularly long periods of immobility are associated with deep, quiet sleep (Middelkoop, van Hilten, Kramer & Kamphuisen 1993), and the movements during quiet sleep are only some rare sudden startles (Alihanka et al 1983, Anders et al 1971). In active sleep there are significantly more body activity, both generalised large movements and small digit movements (Alihanka et al 1983; Anders et al 1971; Hakamada, Watanabe, Hara & Miyazaki 1981; Kirjavainen et al 1996a; Sadeh et al 1995; Thoman & Tynan 1979). In newborns about 90% of body movements occur during active sleep (Junge 1980). Active sleep is also characterised with eye movements and facial impressions (Anders et al 1971; Aserinsky & Kleitman 1955; Dement & Kleitman 1957; Falck 1983). In active sleep the occurrence of movements is phasic, and isolated in quiet sleep (Thoman & Tynan 1979). Sleep is more active in infants, and the amount of activity and movements decrease with age (Erkinjuntti 1988; Fukumoto, Mochizuki, Takeishi, Nomura & Segawa 1981; Sadeh et al 1995) just as the amount of active sleep. The amount of movements reaches the individual base level around the age of 9 to 13 months, a level of activity that is very stable for the individual despite of the great interindividual variation. The amount of totally silent epochs also increase (Fukumoto et al 1981).

With the SCSB-system all the movements can be detected at once (Alihanka & Vaahtoranta 1979; Alihanka, Vaahtoranta & Saarikivi 1981). The subject is laying on a mattress with a sensory system that records all the movements. Respiratory movements and those caused by the heartbeat (ballistocardiogram, BCG) can be differentiated from the raw signal. The system is inexpensive and comfortable, no wires are attached to the subject, and the equipment is easy to use at homes or hospitals, so the subject can sleep as freely and normally as possible. The use of SCSB has been studied with both adults and children, and both normal and abnormal sleep has been investigated. Sleep staging can successfully be done by scoring the SCSB parameters into active sleep, intermediate sleep and quiet sleep according to the activity of moving, regularity of breathing and the regularity of heartbeat. In infants, heartbeat signal is too weak and can easily be disturbed by the noises of the environment so it is not a reliable parameter in sleep staging in infants, but other two parameters can be used reliably (Erkinjuntti 1984). With adults this

staging was successfully done by Kaartinen, Erkinjuntti & Rauhala (1996a) and Alihanka and co-workers (1983), and with children or infants by Kirjavainen and his colleagues (1996a&b) and Erkinjuntti (1987). Softwares for the automatic analysis of the SCSB data have been developed, and some of them and their accuracy have been studied by Salmi and Leinonen (1986) and Kaartinen and colleagues (Kaartinen, Erkinjuntti & Rauhala 1996b), both gaining reliable results. These studies were made with adult subjects only, and the purpose of this study is to examine whether the automatic analysis can also be used with infants.

2. Subjects and Methods

Polysomnographic and SCSB recordings were carried out with 217 new-borns during their first week of life as a part of the Jyväskylä Longitudinal Study of Dyslexia. Recordings were made in the EEG laboratory of the Central Hospital of Central Finland. EEG with 8 electrodes, eye movements and EMG were registered. Respiratory movements, ballistocardiogram (BCG) and body movements were filtered and amplified from the SCSB raw data by using BR-CPA8 preamplifier. The three SCSB signals and the standard sleep polygraphy were recorded by Racal Store 14 Instrumentation Recorder. Recording sessions were also videotaped.

From this group the longest possible sleeping epochs of 15 infants, nine girls and six boys, were chosen for the present study. Sleep registrations vary from 24 to 74 minutes and each of them contain all three sleep stages (i.e. active sleep, intermediate sleep and quiet sleep).

A clinical neurophysiologist did the sleep stage scoring (active, intermediate and quiet sleep) with EEG, EMG, eye movements and respiration for the data in 30 seconds epochs. Staging was done according to the criteria presented in the sleep stage scoring manual for infants (Anders et al.1971). The SCSB data of the infants was automatically analysed by the BR99-software, a software specially

developed for SCSB analysing which automatically classifies the epochs to quiet, intermediate or active sleep. Three variables were chosen for the SCSB analysis: variation of respiratory amplitude, variation of respiratory frequency, and small body movements lasting 0-10 seconds. Variation of BCG was left out from the analysis because it doesn't give so reliable data in infants although is a good variable in adults' sleep studies. The fact that BCG recording is very easily disturbed by any low-frequency noise in the environment and the hospital ward is usually too restless for obtaining reliable data of BCG variation in infants (Erkinjuntti 1984), supported the decision to leave this variable out from the analysis. Small movements, respiration amplitude variation and BCG are the ones that best correlated with the polysomnographic sleep stage scorings, but also variation of respiration frequency correlated well (Kaartinen et al. 1996b). So after leaving BCG out from this study, variation of respiration frequency was included. According to Haddad and co-workers (1987), variation of respiratory cycle time, i.e. respiratory frequency, allows good separation of quiet and active sleep.

On the basis of the chosen variables the software calculates a total variation score for every three minutes and classifies the 3-minute epoch either active, intermediate or quiet sleep so that epochs with large amount of variation are classified active sleep and more static epochs are classified quiet sleep. The software gives 0 to 9 points for each variable, so the maximum variation score with three variables is 27. The borderlines for the sleep stage classification can be edited by the software. In this study epochs with up to 17 variability points were classified quiet sleep, score 18-19 was classified intermediate sleep and from 20 points onward was classified active sleep. Knowing that infants have only about 15 percent intermediate sleep, the borderlines of this stage were kept narrow. With these borderlines approximately the same frequency of the three sleep stages was reached with the sleep stage scorings of the neurophysiologist. The two different classifications, the one by the neurophysiologist and the one made by BR99 software, were then compared.

A qualitative analysis was also made for the epochs which showed the biggest disagreement between the two methods.

3. Results

The frequencies of EEG-based sleep stages and the classified SCSB activity are crosstabulated in Table 1. The partial percentages of different sleep stages in the analysis of the neurophysiologist were 54 for quiet sleep, 18 for intermediate, and 30 for active sleep. With the BR99 analysis the same partial percentages were 52, 17 and 31, respectively. The few epochs, when the infant was awake according to the motor active wakefulness (MAW)-variable calculated by the software, were coded active sleep because MAW is not considered a reliable indicator of wakefulness (Karttinen et al. 1996b). The total agreement percent was 59 between the traditional polysomnographic scorings and the BR99 scorings. The agreement percent varied from 34 to 76 between the infants. Examples of good agreement of quiet sleep are presented in Figure 1A, and of active sleep in 1B.

Table 1.

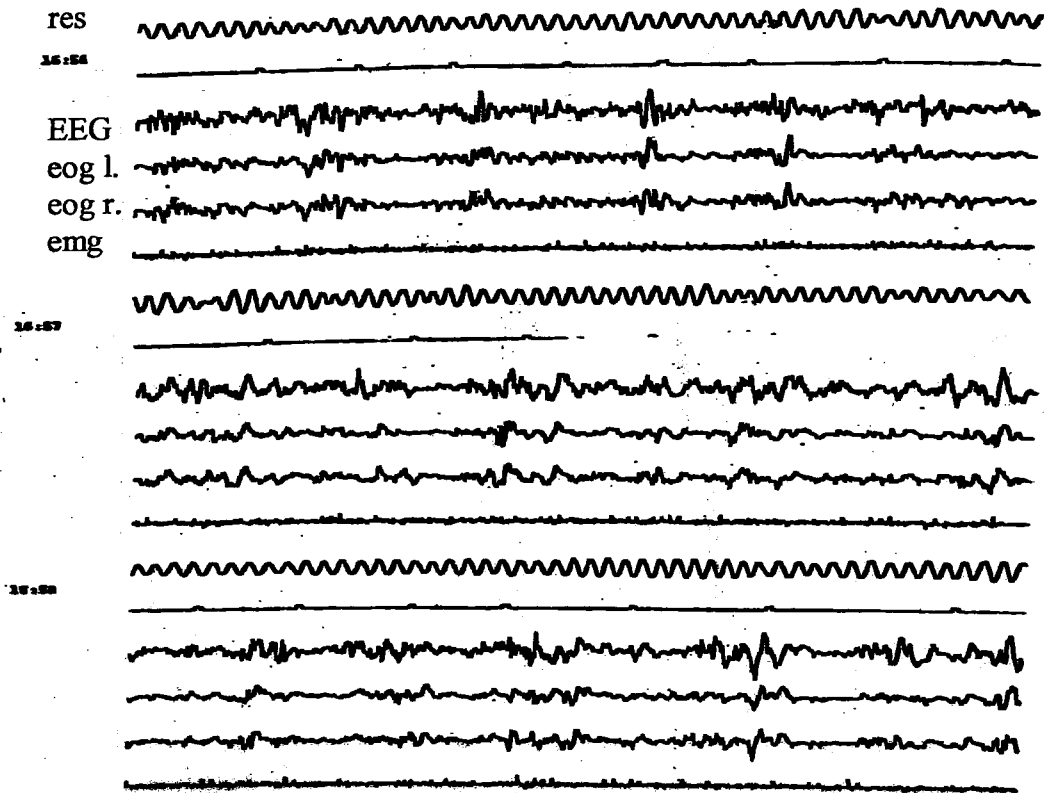
		SCSB			Total
		QS	IS	AS	
EEG	QS	530	62	126	718
	IS	94	33	109	236
	AS	80	67	227	374
Total		704	162	462	1328

Crosstabulation of standard sleep stage classification (EEG) and automatic analysis of SCSB data. Units are 30-second epochs.

It seems that the borderline values that we used for the different sleep stages are good for some but not for the others, and that refers to large interindividual variation between activity levels in infants. Other borderline values were also tested, but the mentioned 0-17 for quiet sleep, 18-19 to intermediate and from 20 upwards gave the highest agreement for the data as a whole. Other borderlines were better for some individuals, for example subject 15, whose sleep was very calm. With borderlines 0-13 for quiet sleep, 14-16 for intermediate and from 17 upwards for active sleep this infant reached agreement percent of 64 instead of 46, which he got with the borderlines used for the whole data. But the borderline values that were good for this calm-sleeping infant were worse for other infants, especially restless ones.

Figure 1 A.

Polysomnographic recording:



SCSB recording:

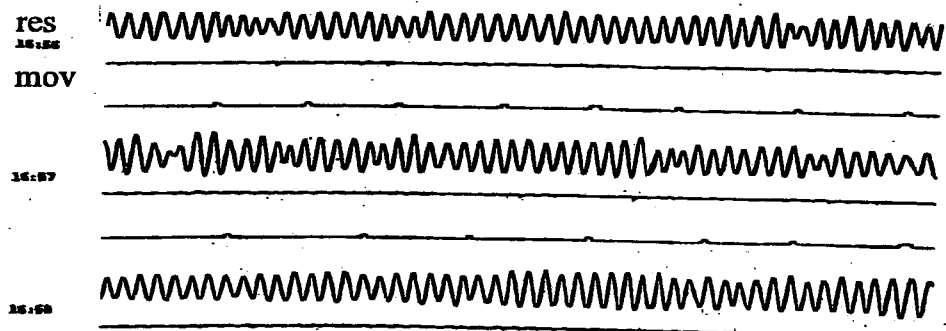


Figure 1 A presents an example of a three-minute epoch which is coded quiet sleep by the neurophysiologist and the BR99-software. Uppermost curve is respiration, the second a signal channel not used in this study, the third EEG C4, the fourth is electro-oculogram of left eye and the fifth the same of the right eye, and sixth line is electromyogram. The SCSB curves are respiration and movements.

Figure 1 B.

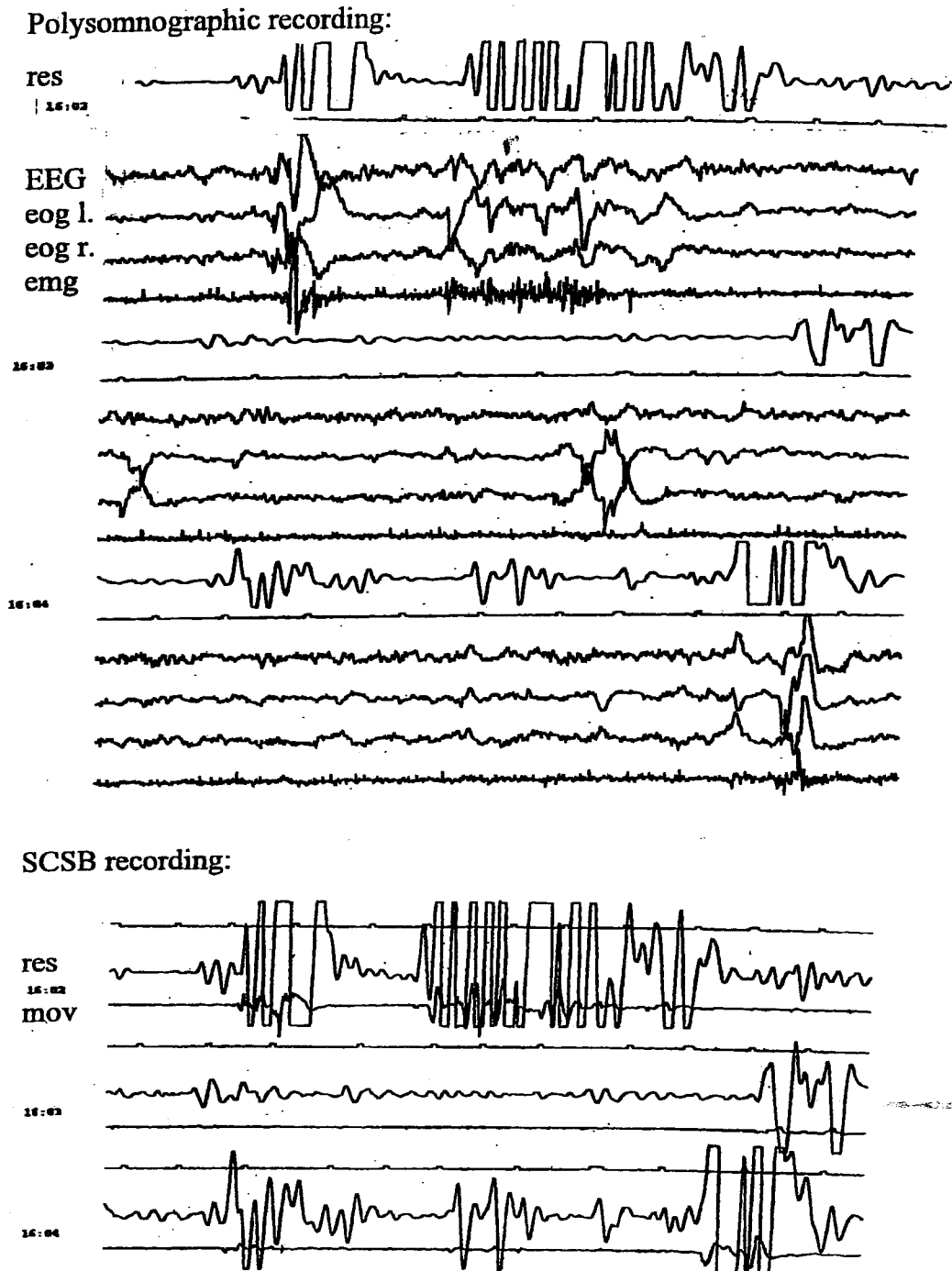


Figure 1 B presents an example of a three-minute epoch which is coded active sleep by the neurophysiologist and the BR99-software. The lines of the curves are the same as in figure 1 A.

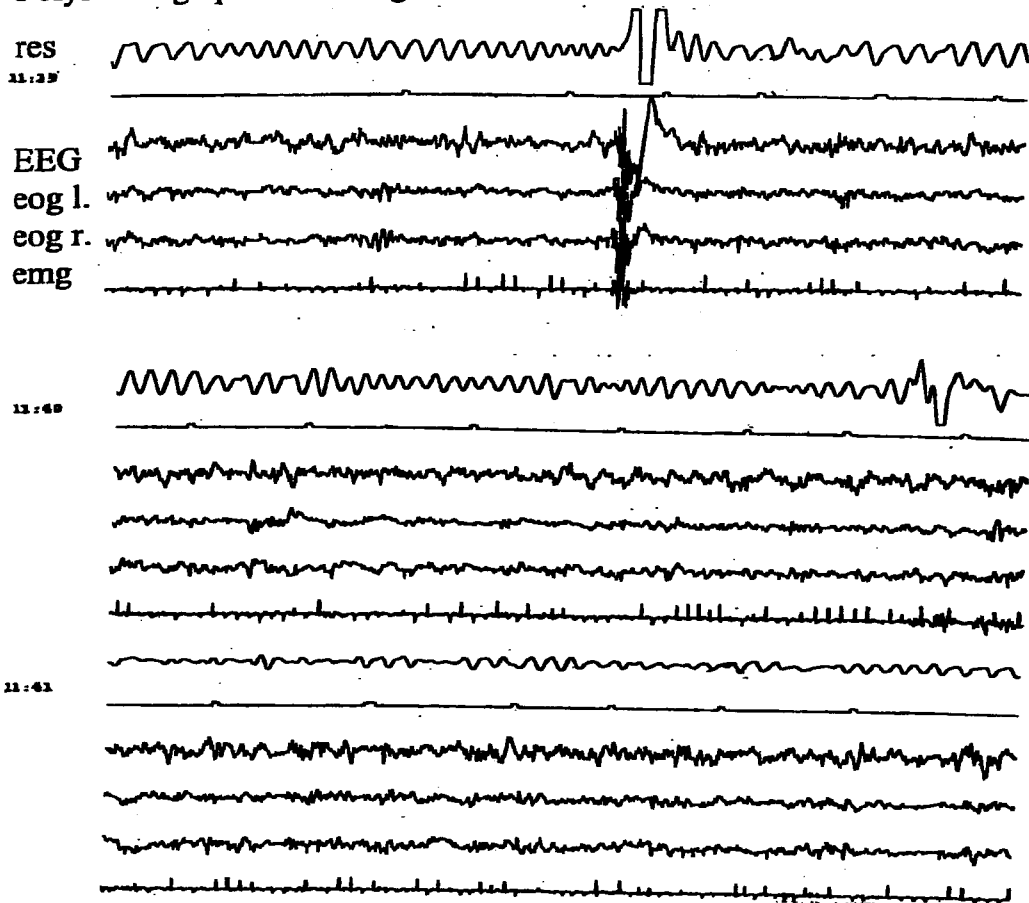
For eleven infants (N=15) the correlation was significant at the 0.01 level between the polysomnography-based scorings and the variability score calculated by the BR99 software, the significant correlations varied from .247 to .674. That indicates, that the software correctly recognises activity, and amount of activity is clearly related to different stages in sleep, but forming such borderlines for the different sleep stages which would be qualified for each individual infant, is difficult. This finding was confirmed by ANOVA which showed that there was a statistically significant difference between the SCSB variation scores and the EEG-based stages $F(2,1333) = 125,1, p < .001$, variation being lowest in quiet sleep and highest in active sleep.

The amount of epochs coded quiet sleep by the neurophysiologist and active sleep by the software was 17,5 %, and in turn epochs coded active sleep by the neurophysiologist and quiet sleep by the software 21,4 %. We took a closer look to these epochs, and found some explanation for the disagreement.

Epochs coded quiet sleep by the neurophysiologist and active sleep by the software showed such a variation in respiration amplitude and frequency, that it is understandably scored active sleep by the software. But at the same time EEG, EOG and EMG patterns are typical for the quiet sleep, and the scoring manual (Anders et al. 1971) only takes respiration frequency (regular-irregular) into account, it doesn't mention the variability of respiration amplitude as a part of sleep stage scoring. Figure 2 on page 10 presents an example of this kind of an epoch from subject 89 (the numbers of the subjects are the original ones used in the Jyväskylä Longitudinal Study of Dyslexia). If the borderline values of quiet sleep were still higher in the software, these kind of epochs would be coded quiet sleep also by the software, but that results to greater disagreement in other stages, and would code really active epochs into quiet sleep. And if all controversial epochs were coded intermediate sleep, the percentage of this stage would have risen high, keeping in mind that infants only have about 15 % intermediate sleep.

Figure 2.

Polysomnographic recording:



SCSB recording:

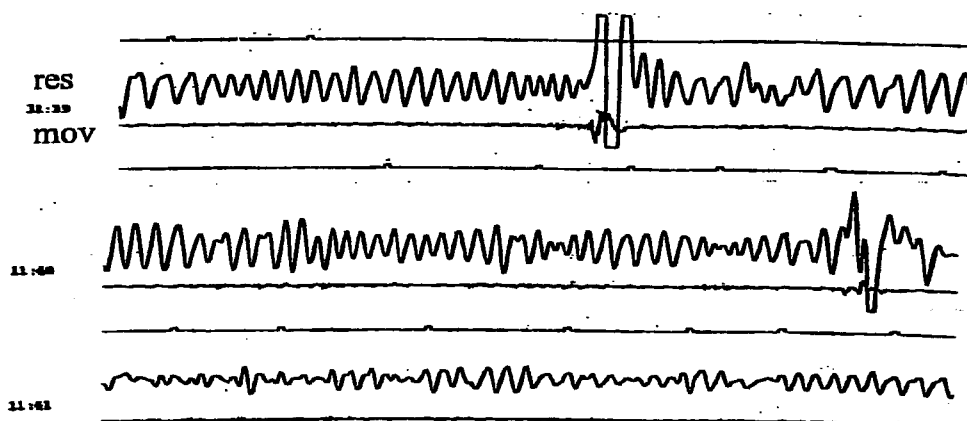
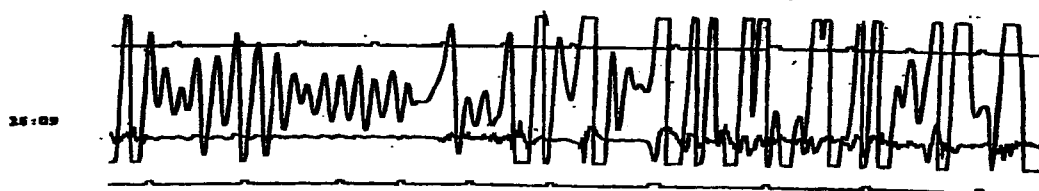


Figure 2 presents an exaple of an epoch taken from data of infant 89. The epoch ^{was} coded quiet sleep by the neurophysiologist and active sleep by the BR99 software. Variations in respiration frequency and amplitude are clear and there are also a couple of small body movements, but other variables are typical for quiet sleep. The BR99 software calculated 22 variation points for this epoch.

Epochs coded active sleep by the neurophysiologist and quiet sleep by the software came out to be harder to explain. Those epochs contained a lot of activity, for example one minute could contain 24 seconds of movements and highly irregular respiration, and still it was coded quiet sleep by the software (Figure 3: subject 15 at 16.09).

Figure 3.



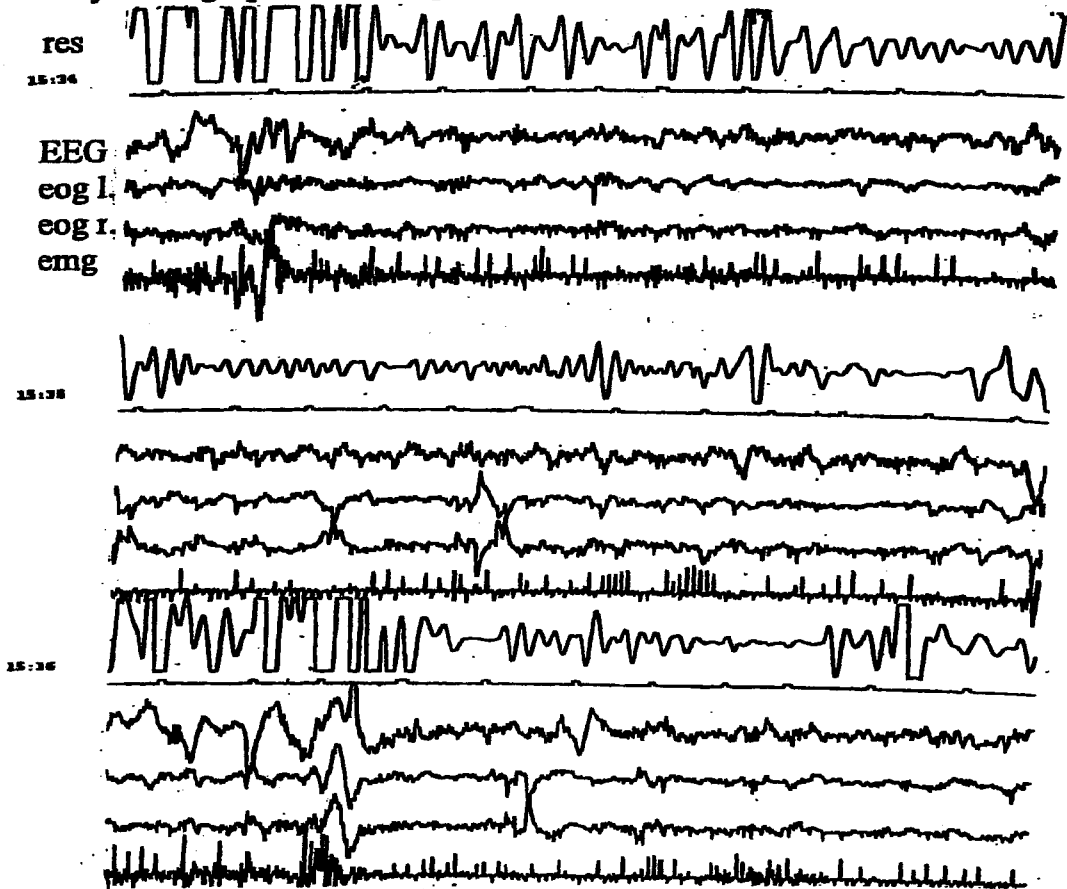
This really active minute contains 24 seconds of movements, but is coded quiet sleep by BR99 because of 16 variability points calculated here. The other minutes in this three-minute epoch resembled this minute chosen for this example. Only the SCSB curves of respiration and movements are shown here.

It seems, that the software sometimes gets confused with really active epochs and cannot calculate the variation score right. With some epochs like this the variation score came close to the set upper borderline of quiet sleep, but if the borderline was lower, the problem described before in this chapter (disagreement when neurophysiologist codes quiet sleep and the software codes active sleep) would be still greater. Same amount of variation points was calculated to remarkably different kind of epochs, examples are shown in Figure 4: 15 variation points for subject 130 at 15.34-15.36 (Figure 4 A on page 12) and the same for subject 7 at 11.22-11.24 (Figure 4 on page 13), epochs that contain clearly different amount of activity and variation. With some really active epochs, when the infant seemed to be awake and constantly moving, the software calculated less than 10 variation points (for example, Figure 5 on page 14:

subject 7 at 10.43-10.45). These clearly refer to confusions in the software. These kind of epochs described above were only few, and if they were left out of analysis, agreement percent between the two scoring methods was a little bit higher, 64 for the whole data and varying from 39 to 82 percents between the infants.

Figure 4 A

Polysomnographic recording:



SCSB recording:

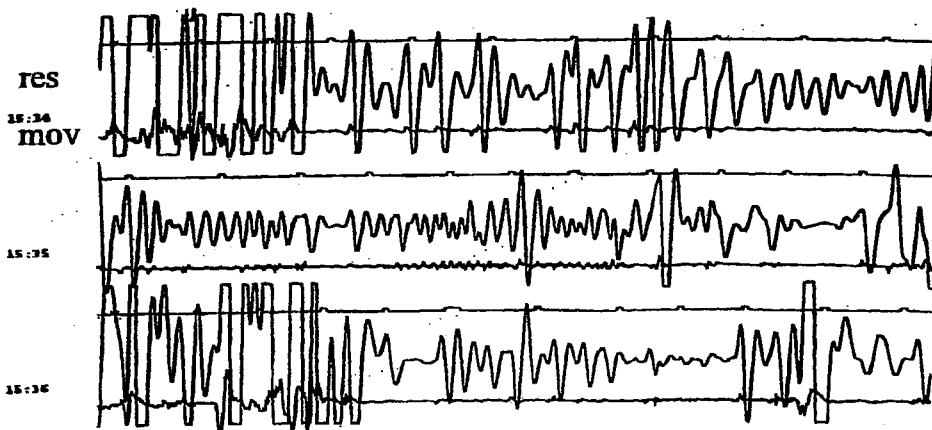
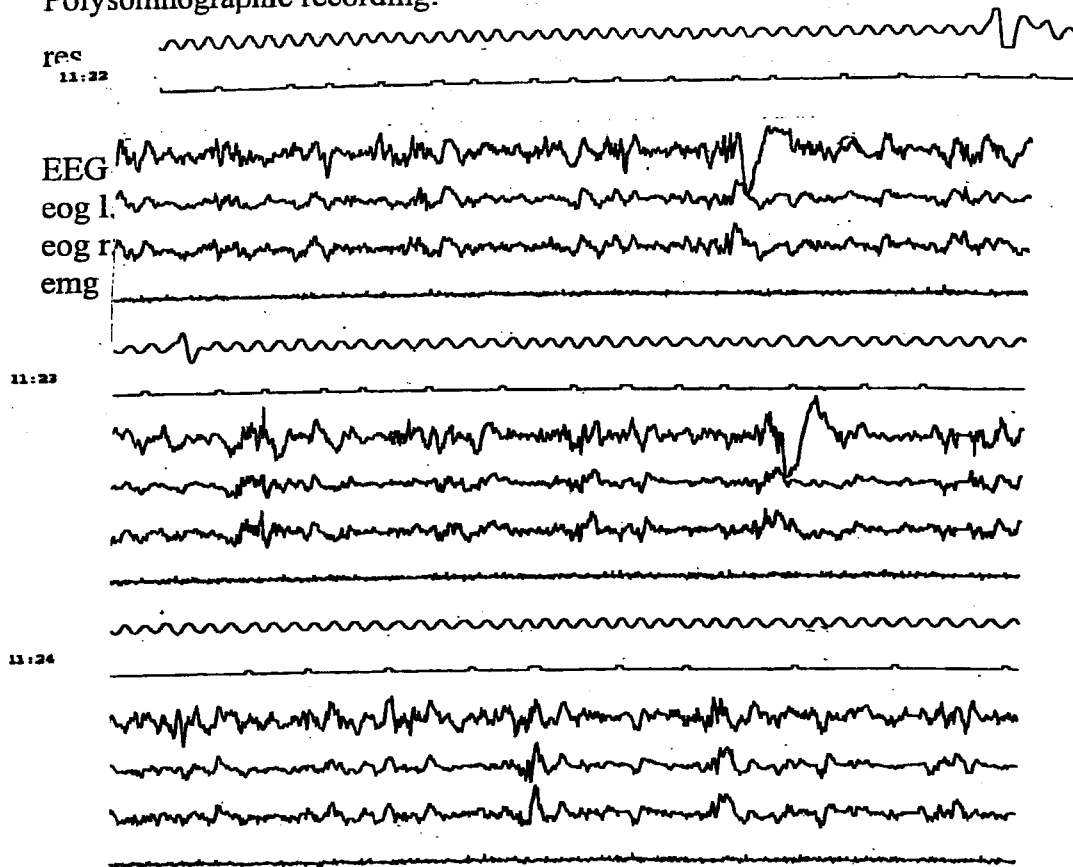


Figure 4 B.

Polysomnographic recording:



SCSB recording:

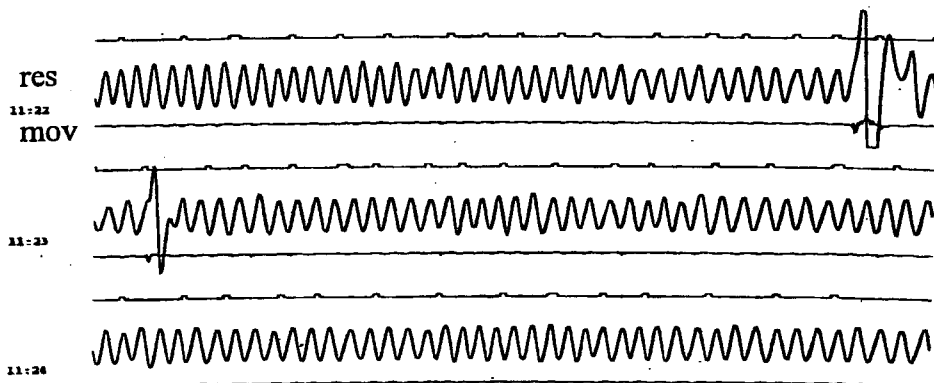
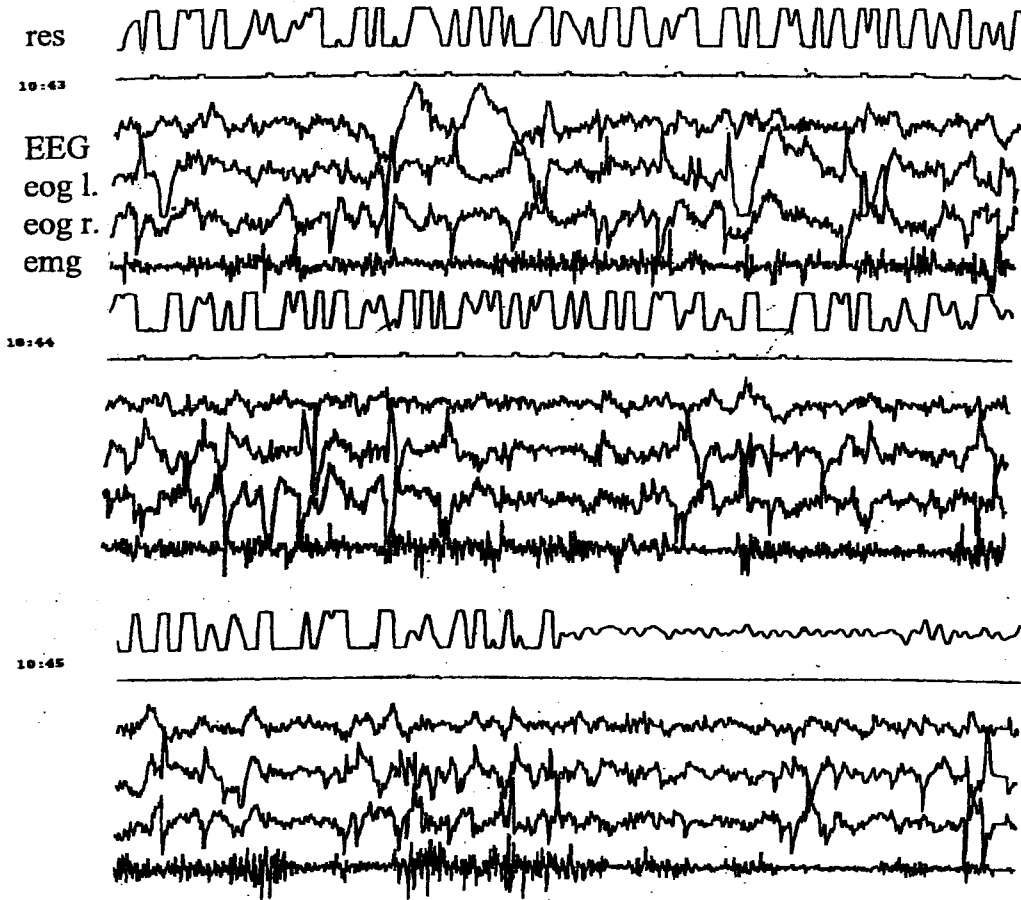


Figure 4 presents two epochs with the same variability score although the epochs look very different. The epoch in 4 A contains markedly more activity and variation than the epoch in 4 B. Since 15 variation points are calculated for both of these epochs, they are classified quiet sleep by the BR99 software. By the neurophysiologist 4 A is classified active sleep and 4 B quiet sleep.

Figure 5.

Polysomnographic recording:



SCSB recording:

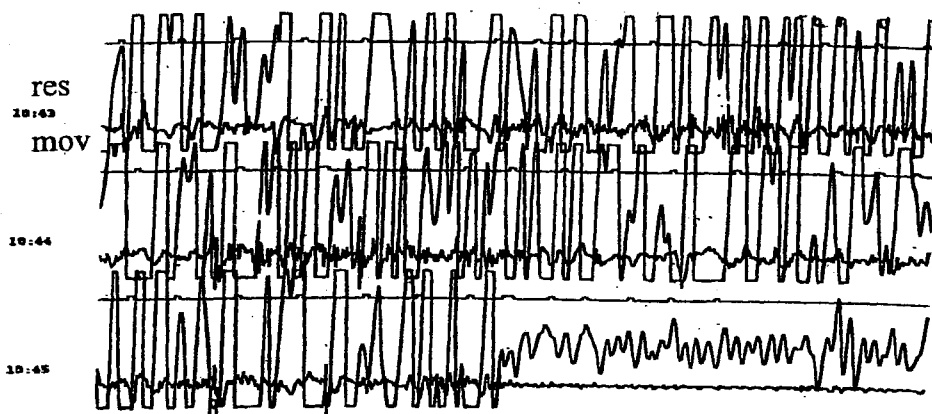


Figure 5 presents an example of a really active epoch, where the BR99 software has only calculated 7 variation points and thus this epoch is classified quiet sleep by BR99. In fact the infants seems to be awake, and the epoch is coded active sleep by the neurophysiologist. That classification seems more correct since short epochs of wakefulness were coded active sleep in this study.

4. Discussion

In this study the automatic SCSB analysis of infants' sleep stages seem to be more complicated than in adults. The agreement percents came out to be smaller than in similar studies made with adult subjects (Kaartinen et al. 1996b; Salmi & Leinonen 1986). New-born infants seem to be more heterogenic group with their sleeping manners than older subjects, perhaps due to their early development. The development of nervous system is thought to control the sleep stages and their development towards adult-like sleep and the new-borns may differ from each other widely when it comes to the regularity-activity aspects of sleep, due to their immature nervous system. In their study Partington and others (1971) noticed that individual infants can be characterised by the motor activity they display, and it is obvious that some persons are more active than others by nature. In our group of 15 infants, there were some with highly regular periods of sleep and some, whose behaviour was more irregular throughout the sleep. Some are calm, some more active, and with some even quiet sleep periods seem to contain more activity and irregularity than expected. Curzi-Dascalova and colleagues (1981) also noted interindividual variation in breathing frequency: some infants breathed more rapidly and some more slowly in all sleep stages.

Some problems were noticed with the software BR99 developed for automatic analysis of SCSB data. First of all, coding of sleep stages is recommended to do for 20-30 second epochs (Anders et al 1971), and the software does the coding for every three minutes. It is too rough, and quick variations are ignored, or emphasised too much. For instance, if one big movement occurs in a 3-minute epoch, the epoch is easily coded active sleep, even though the epoch would otherwise be silent and regular in breathing. In infants the different sleep stages seem to vary quickly and the software cannot keep up with them by analysing the data in 3 minutes epochs.

The second problem clearly associated with the software was confusions with calculating correct variation score for really active epochs. A clear logic wasn't

found how the software does the calculating, and thus anything couldn't be done about it.

Other problems with coding were associated with the controversial information that the used variables showed. If polysomnographical recordings show the typical patterns of quiet sleep, but respiration is irregular, which one you believe? A problem was faced which was already mentioned in 1969 by Dittrichova: when several different parameters are used for staging, what if they show controversial patterns? Changes of the parameters are shown at different times during the changes of stages. For example according to the study of Dittrichova (1969) EMG typical for active sleep still persisted when the other parameters showed patterns typical for quiet sleep. All epochs like this cannot be coded intermediate sleep, or its percentage will rise too high, and it is not meant to be a rubbish-bin of unclear epochs. A neurophysiologist would prefer the polysomnography, whereas the SCSB system concentrates on movements and regularity of breathing, and the disagreement is obvious. The manual for sleep stage scoring in infants (Anders et al. 1971) tells to code breathing either regular or irregular on the basis of frequency variations, whereas the SCSB-system also takes changes in respiration amplitude into account, and the amplitude variations are shown to correlate with different sleep stages (Kartinen et al. 1996b). This is a clear lack in the manual.

The SCSB recording system is very sensitive, which is both good and bad. Understandably it is good for noticing all the minor movements of the body, the system registers all movements as big as and bigger than a heartbeat. But it is also sensitive to stimuli from the environment. During the registrations the parent of the infant was allowed to stay in the room and follow the study, and when the infant was awake and crying, the parent often came to calm the baby, and stayed there even when the baby was asleep again. Touching an infant in any way causes stimuli to the SCSB registration, and is analysed to be the infant's own movement. Even moving a baby's blanket or walking too near the recording system causes this noise. With infants it is harder to stay away from the recording system than when registering adults.

Also the registrations were not that long, lasting from one to two hours, and the amount of time that the infant was asleep and could be used for this study, was still shorter. Perhaps longer recording sessions, e.g. at night, would give more reliable results.

Still the SCSB system is useful for infants because of its easiness for the subject and the staff. The system is simple to use and inexpensive, and the infant's sleep is not disturbed by any attached wires or electrodes, feedings and other acts of care can be done freely, if those epochs are afterwards deleted from the data. Manual scoring of sleep stages on the basis of SCSB data has reached reliable results both in adults and infants (Alihanka 1983, Erkinjuntti 1987, Kaartinen et al. 1996a, Kirjavainen 1996a&b), and automatic staging has been successful in adults (Kaartinen et al. 1996b, Salmi & Leinonen 1986), so the future looks bright for automatic staging for infants also. Automatic analysis would offer great opportunities for the use of SCSB in clinics when no time would be needed for scoring but the information would come straight out from the computer. Since the software already exists and is useful in adults, hopefully it will be developed further to meet the special needs of infant sleep study. The software was developed for clinical use, but is now too complicated and the accuracy of sleep stage scoring is poor for infants. The manual is not clear, for example the system how the BR99 calculates the variation points is not explained and thus the system cannot be edited by the user. And since the calculation seems to be one of the biggest problems causing confusions, attention should be paid there. Another great problem is the classification in 3-minute epochs which is too rough, and either this classification system cannot be changed to the recommended 20 or 30 second epochs by the user.

5. References

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