Teleassistance of the elderly : development of nocturnal ambulatory actimetry

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6th January 2006

Scheme of presentation

- Introduction of the subject
- Purpose of the study
- Introduction to ‘Gardien’
- Methodology
- Results
- Discussion
- Conclusion

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A few definitions (1)

- Teleassistance : to deliver assistance at a remote place by use of communication technologies
- A range of terms associated with teleassistance, for example : telesurveillance, telemonitoring, telecare, telehealth, televigilance, telemetry, ...)

Teleassistance : classification

(Doughty et al. 1996)

- First generation : active telealarm with a *panic* button in case of emergency
- Second generation : passive telealarm with artificial intelligence
- Third generation : establishment of contact in the 'virtual neighbourhood' and improvement of the quality of life

Teleassistance : classification

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2nd generation teleassistance systems

- They are equipped with sensors that monitor different parameters continuously or continually
- They are therefore capable of automatically producing an alarm when an abnormal event occurs
- Disadvantages :
  1. False alarms (not 100% specific)
  2. Absence of alarm (not 100% sensitive)

How can teleassistance help the elderly persons ?

- It is true that teleassistance can help the elderly persons at risk, but
- Little convincing information is currently available on the manner in which it can help them, however
- That must not involve them unnecessarily, and above all, the aid provided much be according to their needs and preferences

A few definitions (2)

- Alarms (Rodríguez et al. 1995) :
  - Active
  - Automatic
  - Passive
- Sensors (Tang et Venables. 2000) :
  - Medical (*e.g.*, measurement of the blood pressure, glucometry, ...)
  - Environmental (*e.g.*, detectors of movement, smoke or fire, bed temperature, ...)

A few definitions (3)

Actigraphy or actimetry : measurement of the activity of an individual :-

- Body-worn : classical method; *e.g.*, wrist actimetry (Someren. 1997)
- Remote : relatively newer method (Couturier et al. 1996)

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Identification of principal risks of the hospitalised elderly

- Falls
- Behavioural problems (*e.g.*, nocturnal wandering, agitation, aggressiveness, ...)
- Fugues

In order to find a solution to these problems

- Installation of a passive infra-red sensor system in the patient's environment (geriatrics department of the university hospital of Grenoble, France)
- Laboratoire Interuniversitaire de Gérontologie de Grenoble (LI2G) in collaboration with INSERM U.558 of Toulouse, France

Principal objectives

- To measure nocturnal activity in a group of elderly patients having cognitive problems compared to a control group of elderly patients *not* having cognitive problems
- To develop an algorithm for the automatic detection of nocturnal hyperactivity

Secondary objectives

- To develop a scale for the night staff in order to get an idea of the quantity of nocturnal activity of the patient
- To assess the acceptability of the system on the part of the patient and his or her family

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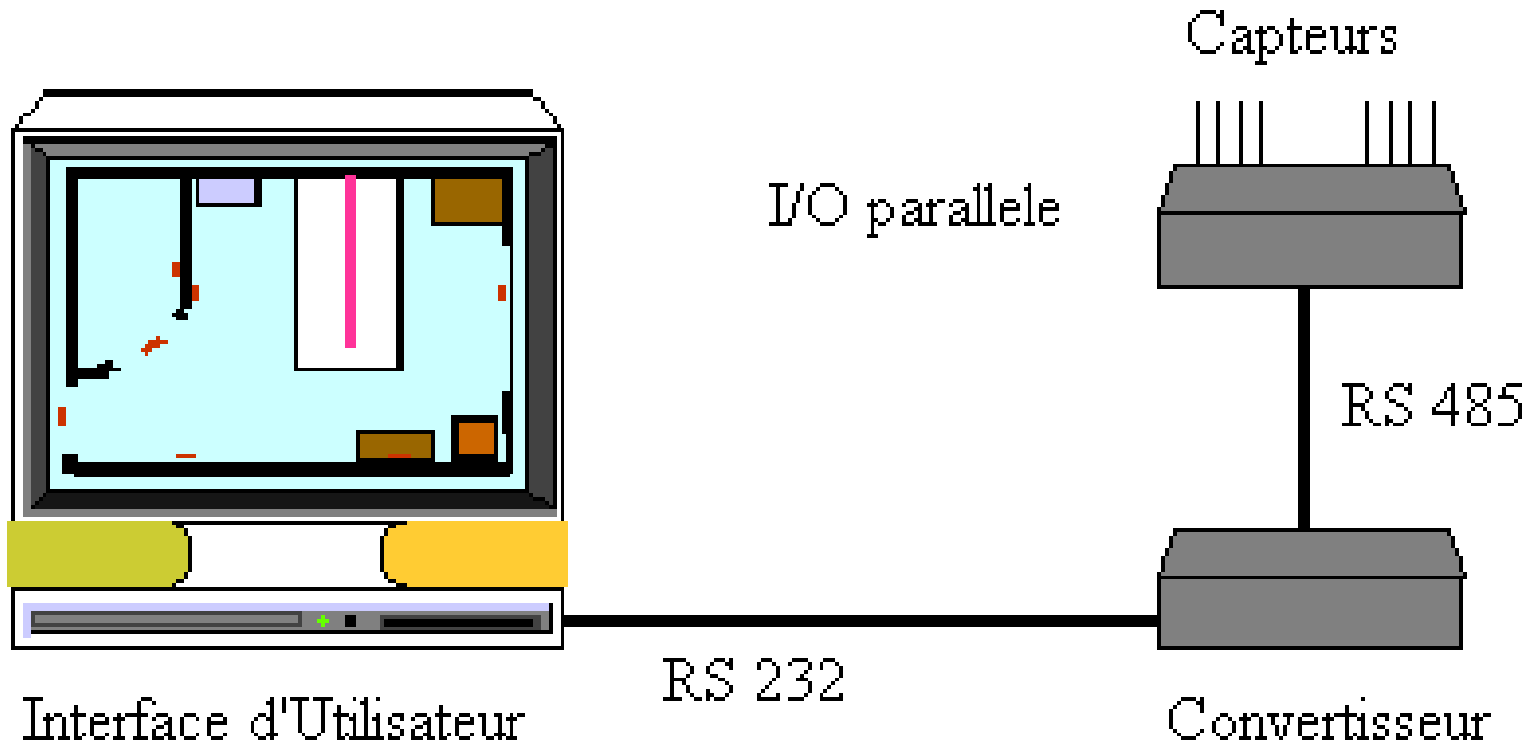
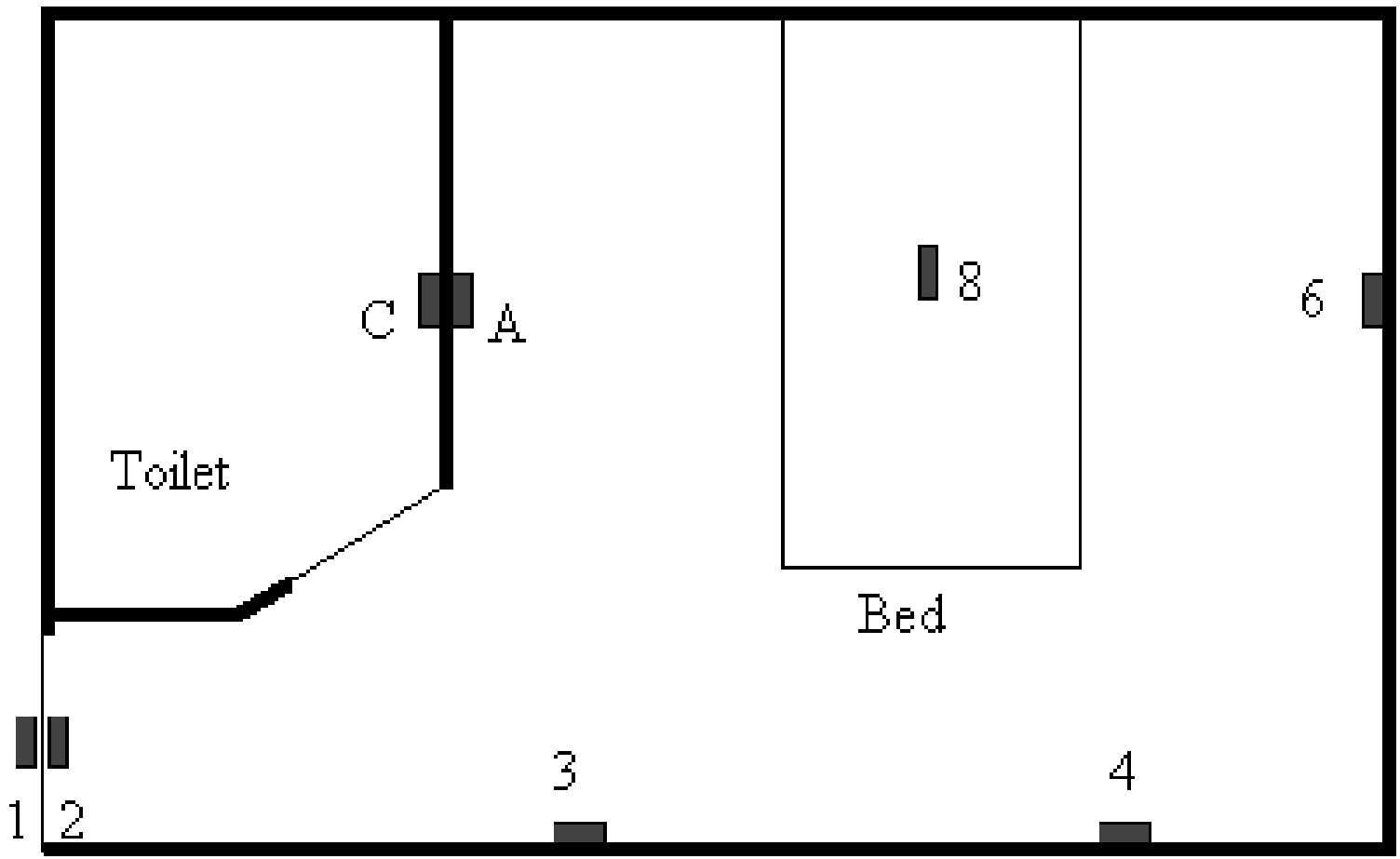
G.A.R.D.I.E.N. system (1)

- *Gérontologie Assistée par la Recherche et le Diagnostic des Incidents et des Errances Nocturnes*
- 8 passive infra-red sensors
- Installed in 2 patient bedrooms : « *chambre intelligente* » or intelligent bedroom
- Connected by cables to a computer, which collected sensor-data continuously and later analysed the data by a programme based on artificial intelligence

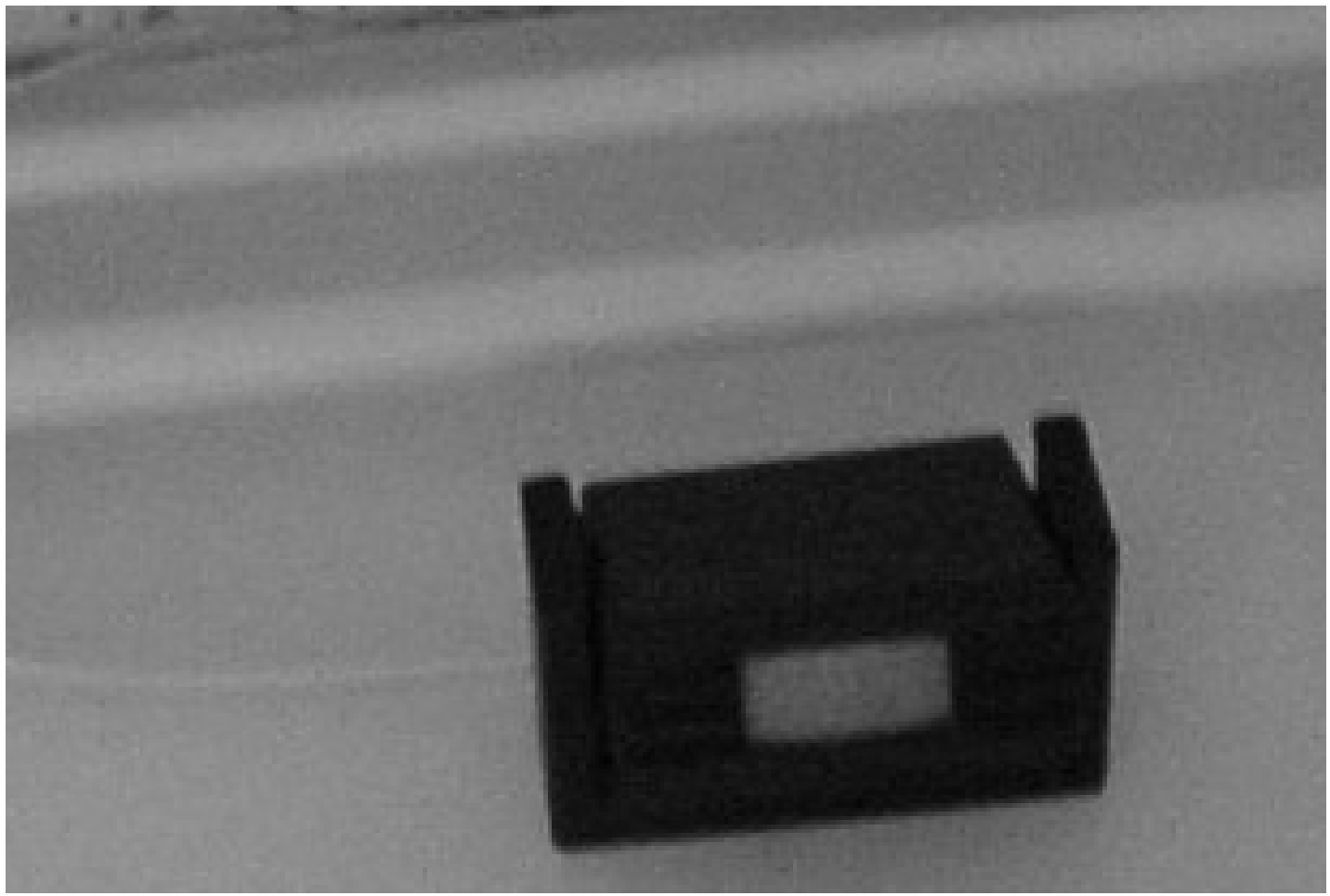
G.A.R.D.I.E.N. system (2)



Plan of the intelligent bedroom



A sensor installed on the wall

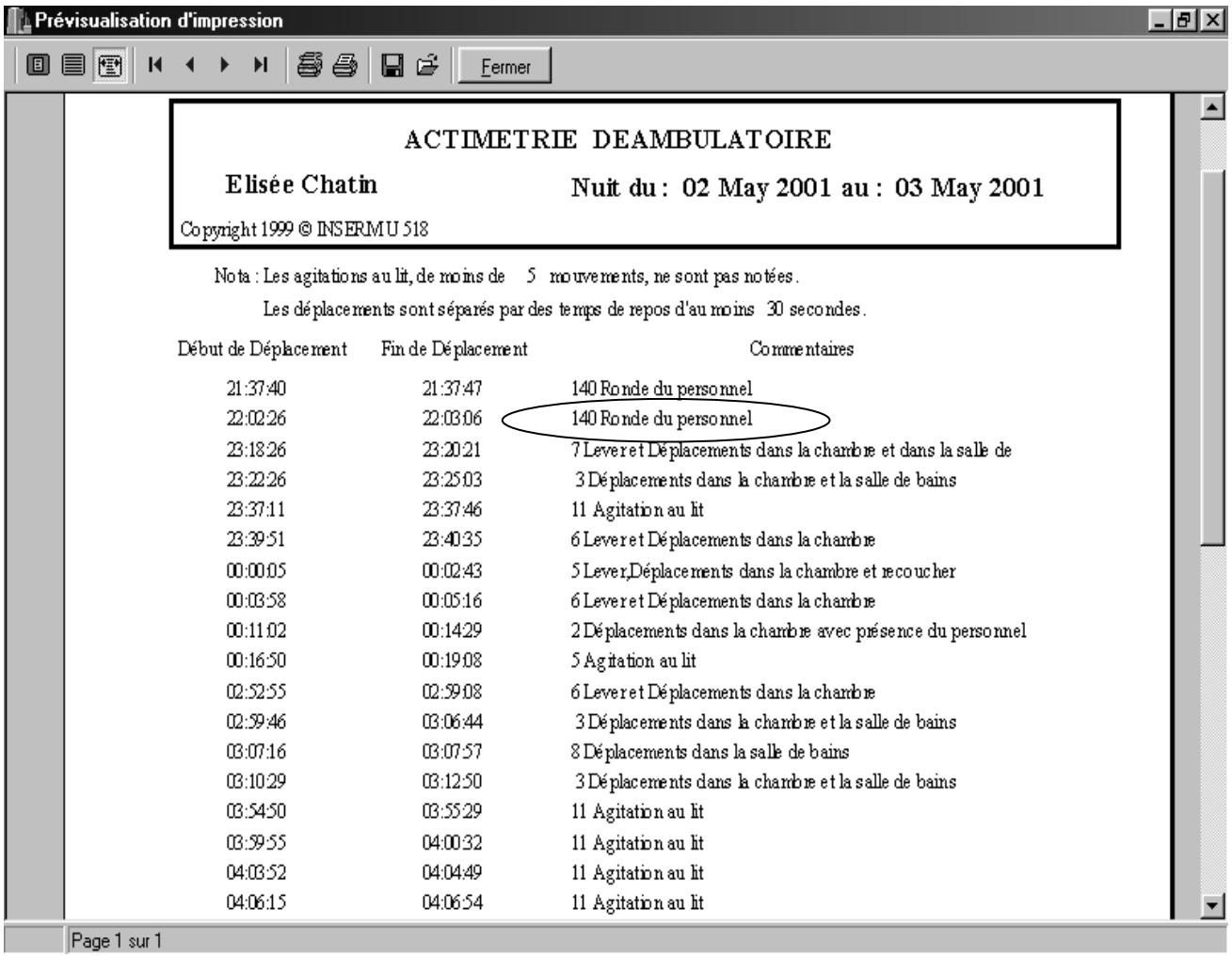


Pilot study of the technical validation of G.A.R.D.I.E.N.

(Banerjee et al. 2003)

- Surveillance from 21:00 until 06:00 next morning
- 97 nights observed in 4 patients
- Comparison of the results of manual analysis and system analysis
- 1637 valid comments analysed manually
- 10 comments among these were not detected by the system
- 1450 movements (system analysis) were in accordance with manual analysis (R_{IC} = 0.986)

Automatic data analysis by the system : 'activity chart'



Prévisualisation d'impression

Fermer

ACTIMETRIE DEAMBULATOIRE

Elisée Chatin — Nuit du : 02 May 2001 au : 03 May 2001

Nota : Les agitations au lit, de moins de 5 mouvements, ne sont pas notées.

Les déplacements sont séparés par des temps de repos d'au moins 30 secondes.

Début de Déplacement	Fin de Déplacement	Commentaires
21:37:40	21:37:47	140 Ronde du personnel
22:02:26	22:03:06	140 Ronde du personnel
23:18:26	23:20:21	7 Lever et Déplacements dans la chambre et dans la salle de
23:22:26	23:25:03	3 Déplacements dans la chambre et la salle de bains
23:37:11	23:37:46	11 Agitation au lit
23:39:51	23:40:35	6 Lever et Déplacements dans la chambre
00:00:05	00:02:43	5 Lever,Déplacements dans la chambre et recoucher
00:03:58	00:05:16	6 Lever et Déplacements dans la chambre
00:11:02	00:14:29	2 Déplacements dans la chambre avec présence du personnel
00:16:50	00:19:08	5 Agitation au lit
02:52:55	02:59:08	6 Lever et Déplacements dans la chambre
02:59:46	03:06:44	3 Déplacements dans la chambre et la salle de bains
03:07:16	03:07:57	8 Déplacements dans la salle de bains
03:10:29	03:12:50	3 Déplacements dans la chambre et la salle de bains
03:54:50	03:55:29	11 Agitation au lit
03:59:55	04:00:32	11 Agitation au lit
04:03:52	04:04:49	11 Agitation au lit
04:06:15	04:06:54	11 Agitation au lit

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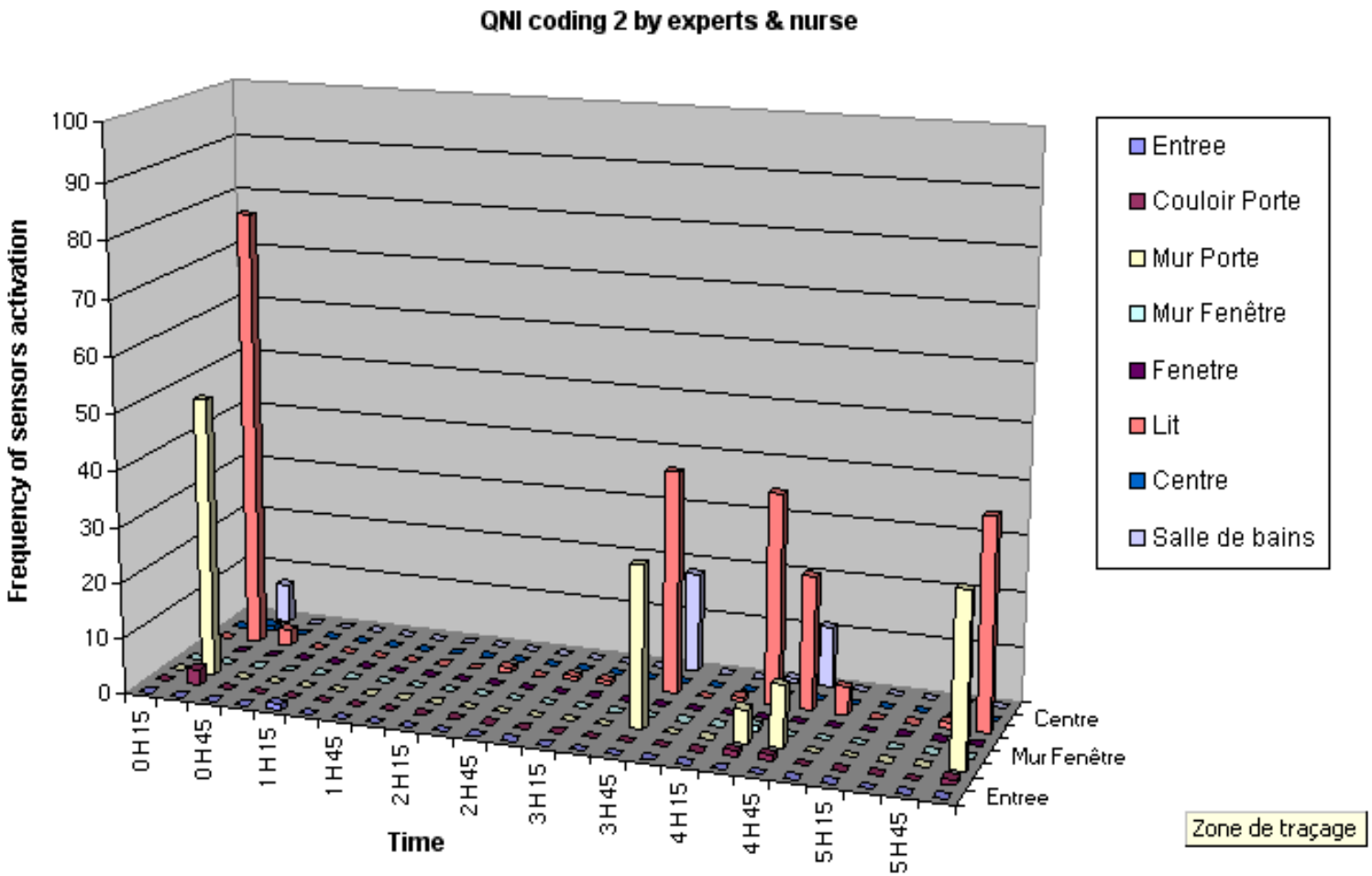
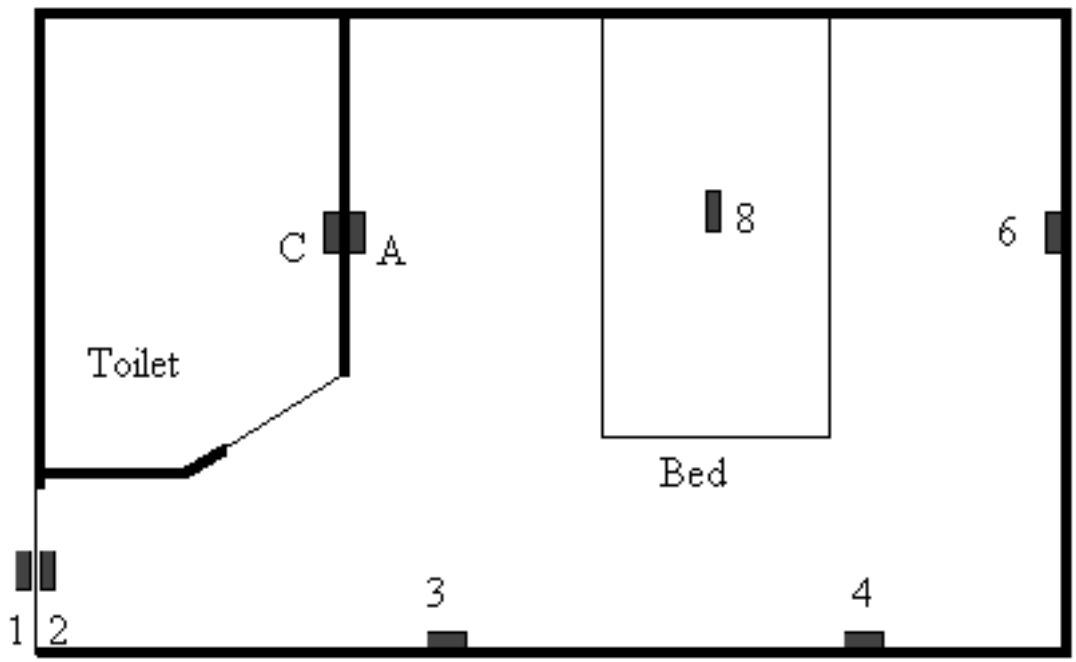
Automatic data analysis by the system : 'actigramme'



Manual analysis of the raw data : ‘visit by the personnel’

1		Wed May 02 22:02:26 2001
		Wed May 02 22:02:30 2001
1		Wed May 02 22:02:31 2001
12		Wed May 02 22:02:31 2001
2		Wed May 02 22:02:32 2001
23		Wed May 02 22:02:34 2001
3		Wed May 02 22:02:36 2001
3	A	Wed May 02 22:02:36 2001
	A	Wed May 02 22:02:37 2001
3	A	Wed May 02 22:02:38 2001
3		Wed May 02 22:02:40 2001
		Wed May 02 22:02:41 2001
3		Wed May 02 22:02:42 2001
23		Wed May 02 22:02:43 2001
2		Wed May 02 22:02:44 2001
12		Wed May 02 22:02:45 2001
1		Wed May 02 22:02:45 2001
		Wed May 02 22:02:47 2001
1		Wed May 02 22:02:48 2001
		Wed May 02 22:02:50 2001
1		Wed May 02 22:02:50 2001
		Wed May 02 22:02:51 2001
1		Wed May 02 22:02:54 2001
		Wed May 02 22:02:56 2001
1		Wed May 02 22:02:57 2001
		Wed May 02 22:02:59 2001
1		Wed May 02 22:03:02 2001
		Wed May 02 22:03:06 2001



What is a ‘valid’ comment ?

- Gardien uses a variable time threshold and a minimum number of sensor activation (state of change)
- In our study, the time threshold = 30 seconds
- And the threshold for the minimum number of sensor(s) activation = 5

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Technical improvements of the system

- Time of surveillance modified : from 10:00 to 08:00 next morning (22 hours)
- This time interval was again divided into : daytime and night-time (11 hours each)
- A 3rd time interval called « *after midnight* » (from 00:00 to 06:00) in order to minimise the « noise »
- The chief parameter measured is the *cumulative* **time** of activity or displacements (seconds)

Simplification of the system data

- Movements by the personnel or visitors (excluded from the analysis)
- Movements by the patient :
  - Movements in bed or near the bed
  - Movements for going to the toilets
  - Movements in the room
- These 3 types of movements are mutually exclusive, whose sum is equal to the total activity

Methods used in the clinical phase

- Two patient groups : **cognitive impairment** (N = 21) and **control** (N = 6)
  - Cognitive impairment group having MMS score < 25
  - Control group having MMS score ≥ 25
- Consent of the patient &/or next-of-kin
- Actimetric data used only for the research in order to establish normative data in the 2 groups
- No. of nights observed ≥ 8 nights (after having passed ≥ 3 nights in the intelligent bedroom)

Number of patients recruited in a few other actimetric studies

- Satlin et al. (1991) studied 27 patients [Alzheimer's disease (AD) versus controls]
- Aharon-Peretz et al. (1991) studied 36 patients (Multi-infract dementia, AD & controls)
- Lavie et al. (1992) studied 50 subjects (Multi-infarct dementia, AD, major depressive disorder & controls)
- Hilten et al. (1993) studied 99 healthy subjects divided into several age-groups and by gender
- Pollak et al. (1997) studied 25 dementia and 18 non-dementia patients
- Yesavage et al. (1998) studied 61 AD patients in a follow-up study
- Lemke et al. (1999) studied 52 depressed patients
- Paavilainen et al. [2005 (*in press*)] studied 16 dementia patients

Recruitment of the patients

- Criteria of inclusion : mobile patients, patients hospitalised $\geq$ 8 nights
- Criteria of exclusion : palliative care patients, bed-ridden patients or those needing help for displacement, patients infected with multi-resistant micro-organisms, patients with acute cardio-respiratory failure, patients having fear of displacement, patients who are a potential threat to the integrity of the material

Clinical data collected from the patients (1)

- General : history, current pathology, social evaluation, treatment given
- Standardised geriatric assessment :
  - Test of balance & gait : single feet standing test, Tinetti's test, get up & go test
  - Level of autonomy : Activities of Daily living (ADL), Instrumental ADL (IADL)
  - Nutritional status : Mini-Nutritional Assessment (MNA)
  - Risk of pressure sore : Waterlow's scale

Clinical data collected from the patients (2)

Cognitive & psychological assessment :

- Mini-Mental State examination (MMS)
- Reisberg's dementia scale & Clinical Dementia Rating Scale (CDR)
- Neuro-psychiatric Inventory (NPI)
- Cohen-Mansfield Agitation Inventory (CMAI)
- Geriatric Depression Scale (GDS)

Clinical data collected from the patients (3)

- External assessment :
  - Zarit's scale
  - Qualitative Nocturnal Impression (QNI)*
- Assessment of the acceptability of the system :
  - Brief Questionnaire for the Evaluation of the Acceptability of Teleassistance Systems (BQEATS)*
- Investigations :
  - Routine blood examination, nutritional bio-markers
  - CT scan

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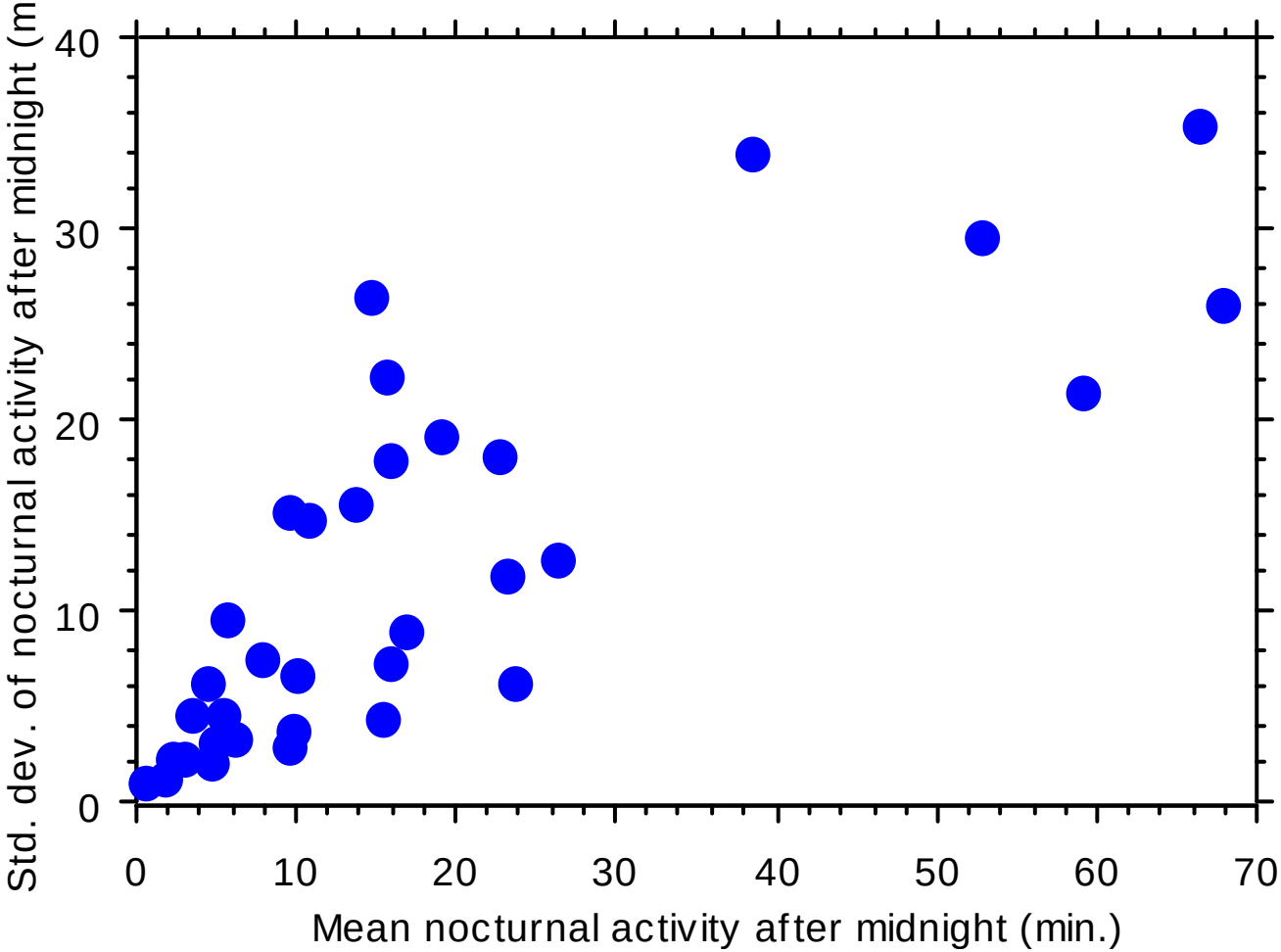
Clinical and actimetric characteristics of the patients

Some initial characteristics of the patients

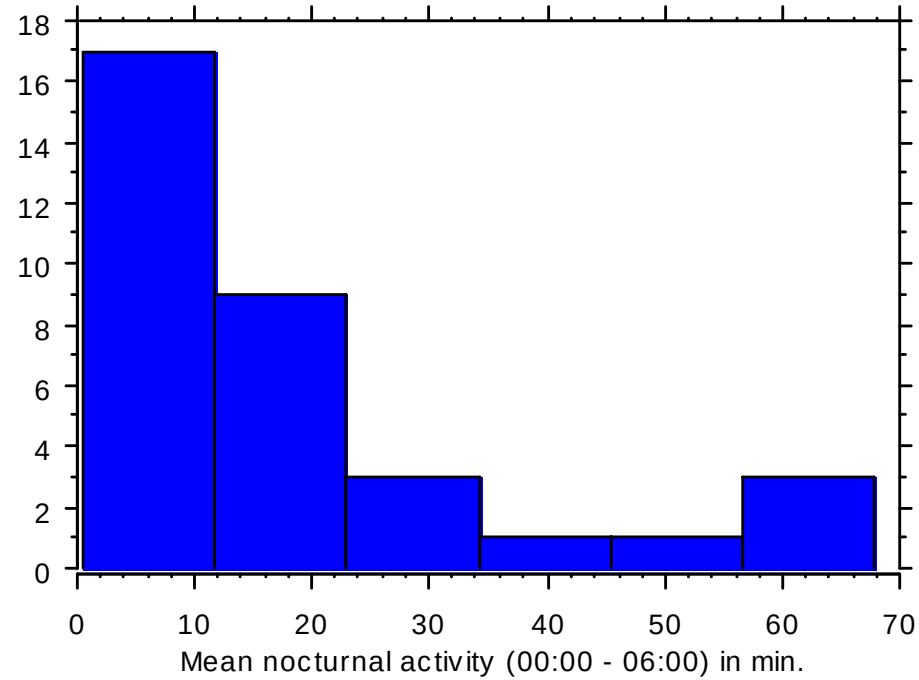
Mean (SD)	**Control group (N = 6)**	**Cognitive impairment group (N = 21)**	**p**
Age - years	81.7 (7.2)	82.4 (6.0)	ns
Gender - M/F (no. of patients)	2/4	9/12	ns
MMS	27.0 (1.3)	13.0 (5.2)	–
MNA	21.3 (6.2)	17.4 (5.5)	ns
Waterlow's score	15.8 (4.5)	11.8 (3.7)	0.05
GDS	12.8 (7.1)	14.2 (5.7)	ns
Psychoactive drugs (no. of patients)	4	20	ns
Extra-pyramidal signs (no. of patients)	2	7	ns

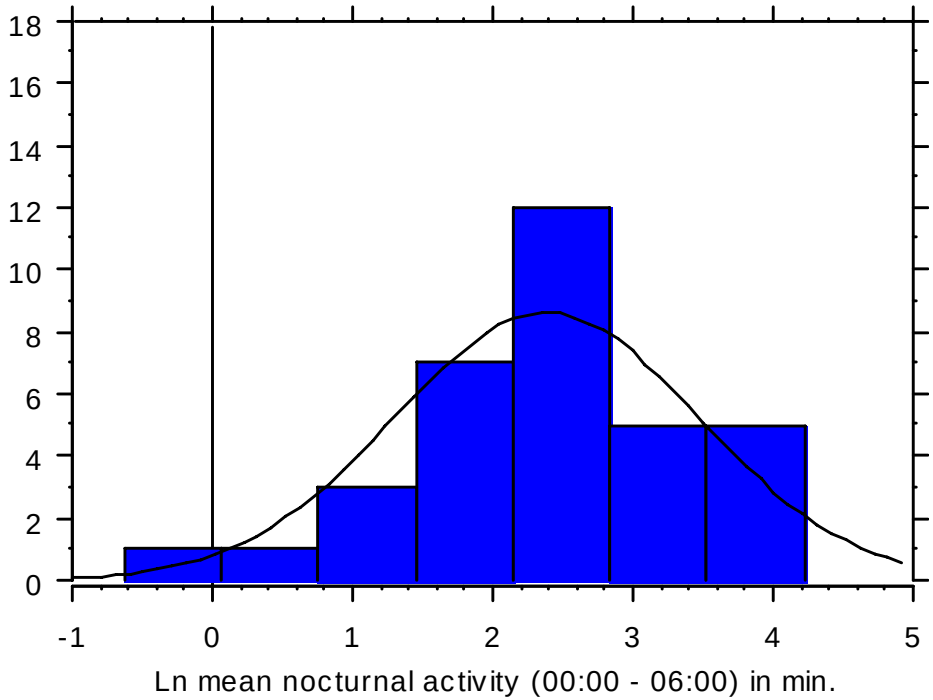
Heteroscedasticity of the data

(M. Bland. Introduction to Medical Statistics, 3rd Ed.)



Spearman's ρ = 0.81, $p < 0.01$ (N = 34)





Histogram of the ***mean duration*** of total nocturnal activity (00:00 – 06:00) (min.) for 34 patients. **Y-axis** denotes the **number of patients**

Histogram of the ***logarithm of mean duration*** of total nocturnal activity (00:00 – 06:00) (min.) for 34 patients. **Y-axis** denotes the **number of patients**

Is there an intra-subject stability of nocturnal activity ?

- Methods : comparing the duration of total nocturnal activity (after midnight) in 23 subjects between the 1st and the 8th night
  - Wilcoxon's test for matched data

    Not significant
  - Spearman's correlation coefficient

    $p < 0.01$
- In 2 studies, intra-subject variability of nocturnal activity was low (Aubert-Tulkens et al. 1987, Sadeh et al. 1991); whereas in 2 other studies, intra-subject variability of nocturnal activity was considerable (Kronholm et al. 1987, Hilten et al. 1993)

Is there an intra-group stability of nocturnal activity ?

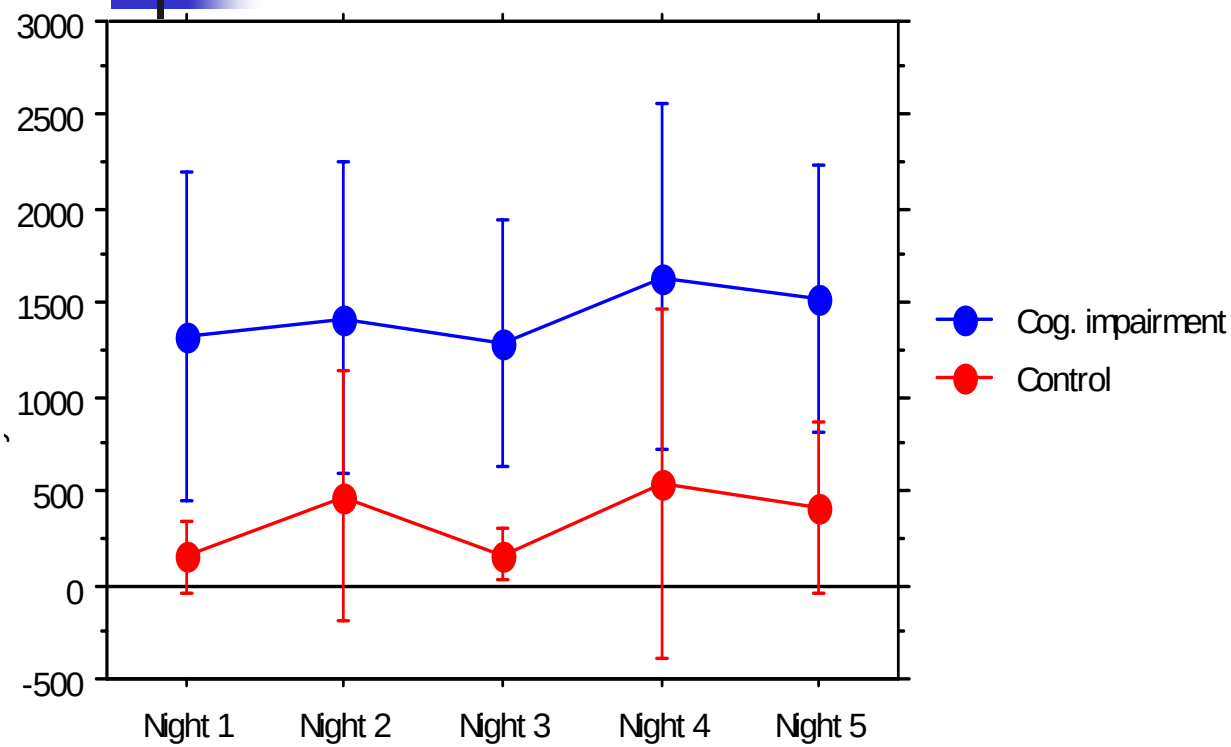


Figure shows the *mean* duration of total nocturnal activity (00:00 – 06:00) in **secondes** (**Y-axis**) for the groups : control & cognitive impairment, for the nights 1 to 5

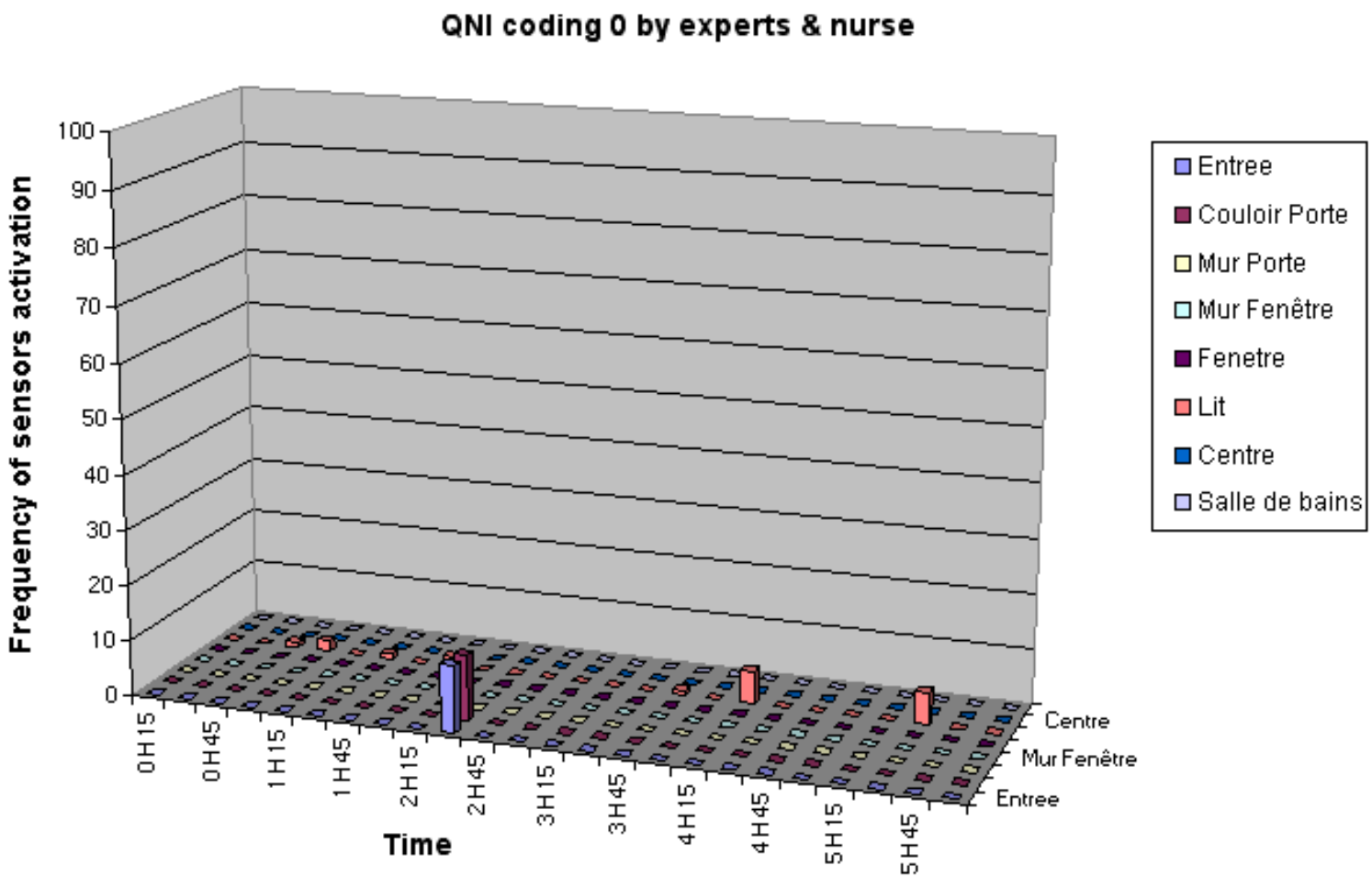
p = not significant in each group for the inter-night variation (ANOVA for repeated measures; Cronbach's alpha = 0.67 for the controls & 0.82 for the cognitive impairment group)

Quantification of nocturnal activity

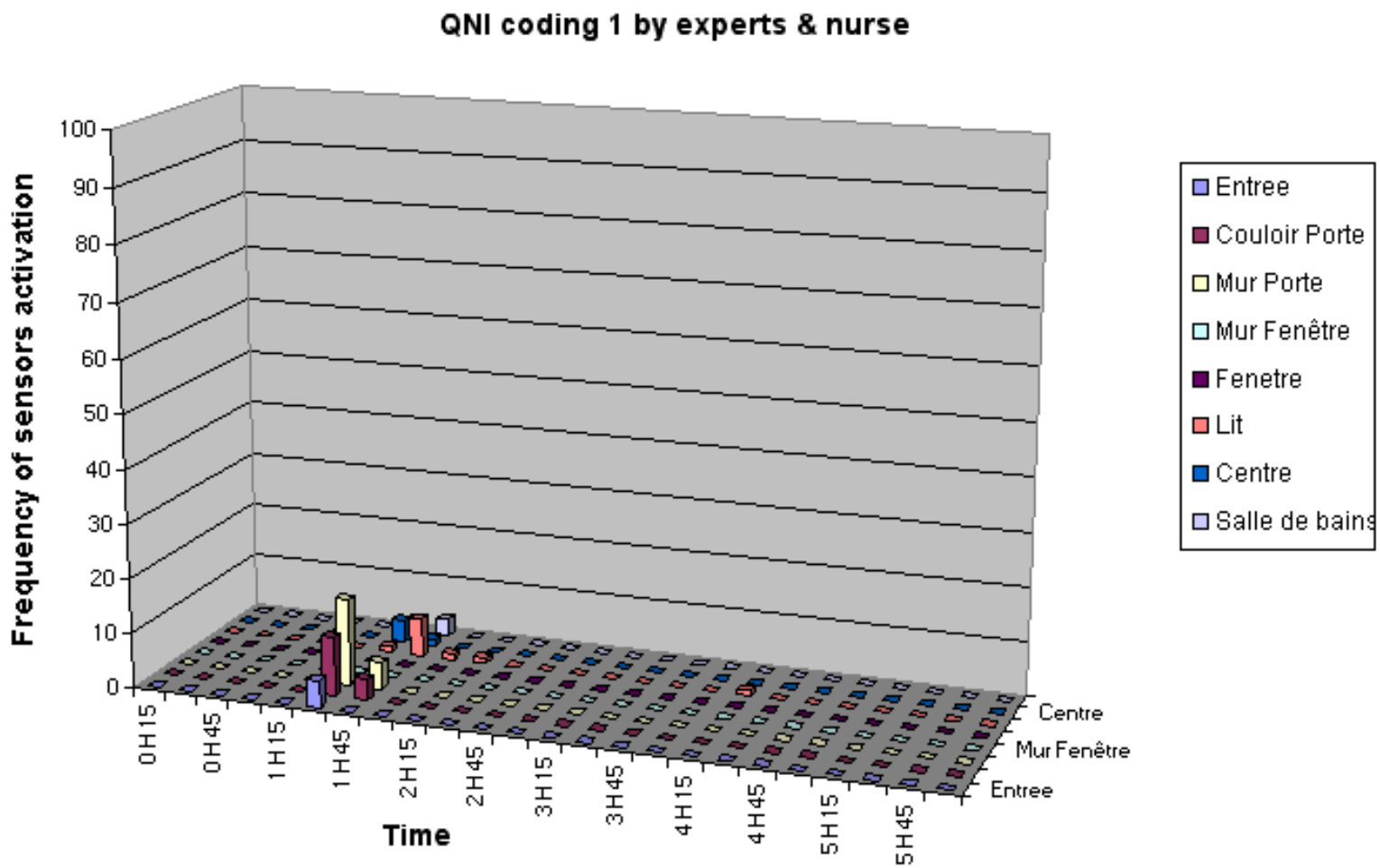
A new scale to quantify nocturnal activity in the elderly

- Qualitative Nocturnal Impression (QNI)
- Definition :-
  - Score 0 = not getting up (*after midnight*) observed in the patient (peaceful night)
  - Score 1 = getting up once or twice (average night)
  - Score 2 = getting up a few times (> 2 times) (mediocre night)
  - Score 3 = several displacements during the night (agitated or hyperactive night)
- Evaluated by the **night staffs** (for **352 nuits**), and
- Evaluated by 3 **experts** separately (by analysis of the system data at the end of the study) = **methode of reference**

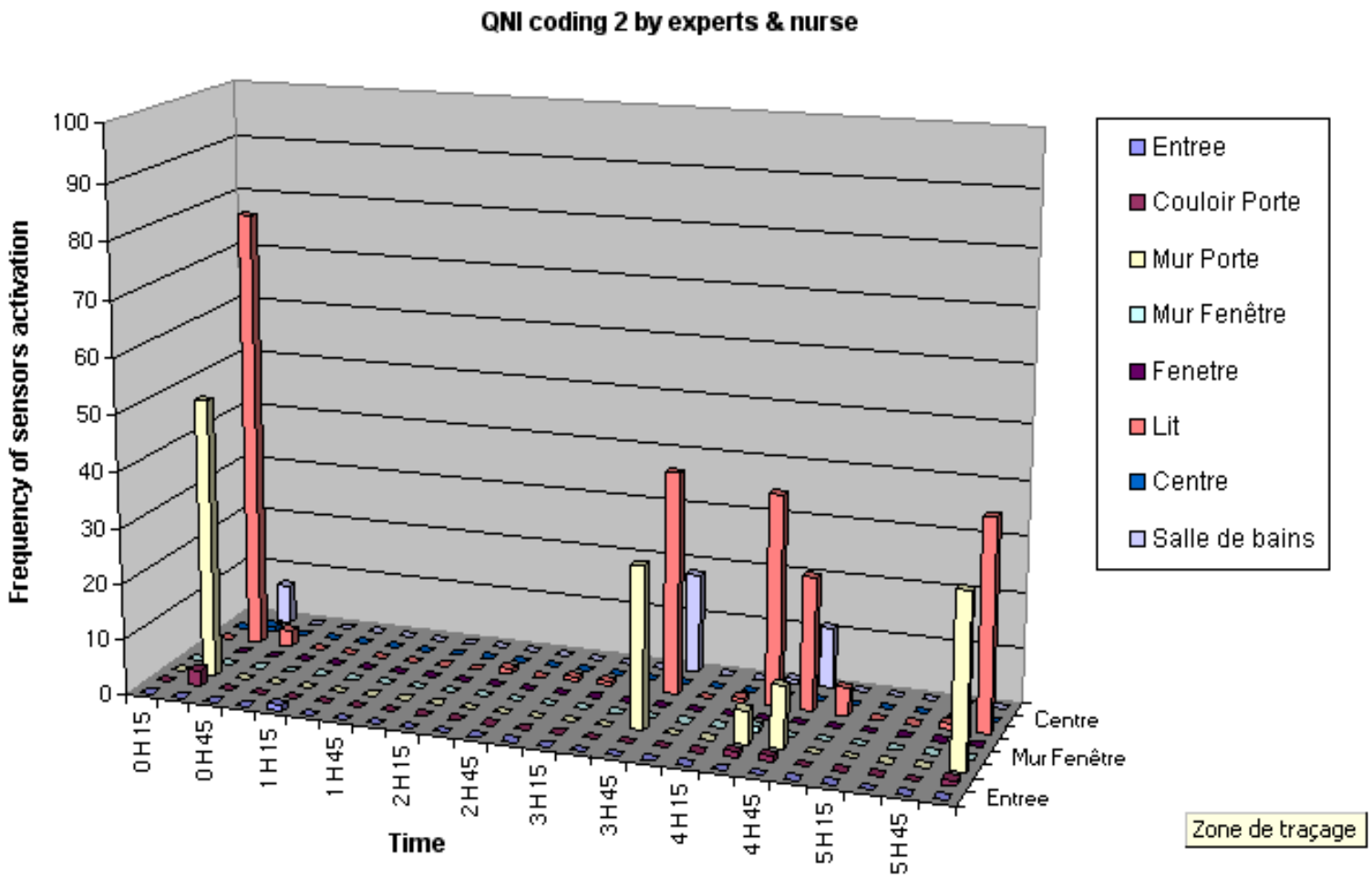
QNI score 0


QNI coding 0 by experts & nurse
Frequency of sensors activation
100
90
80
70
60
50
40
30
20
10
0
0H15
0H45
1H15
1H45
2H15
2H45
3H15
3H45
4H15
4H45
5H15
5H45
Time
Centre
Mur Fenêtre
Entree
Entree
Couloir Porte
Mur Porte
Mur Fenêtre
Fenetre
Lit
Centre
Salle de bains

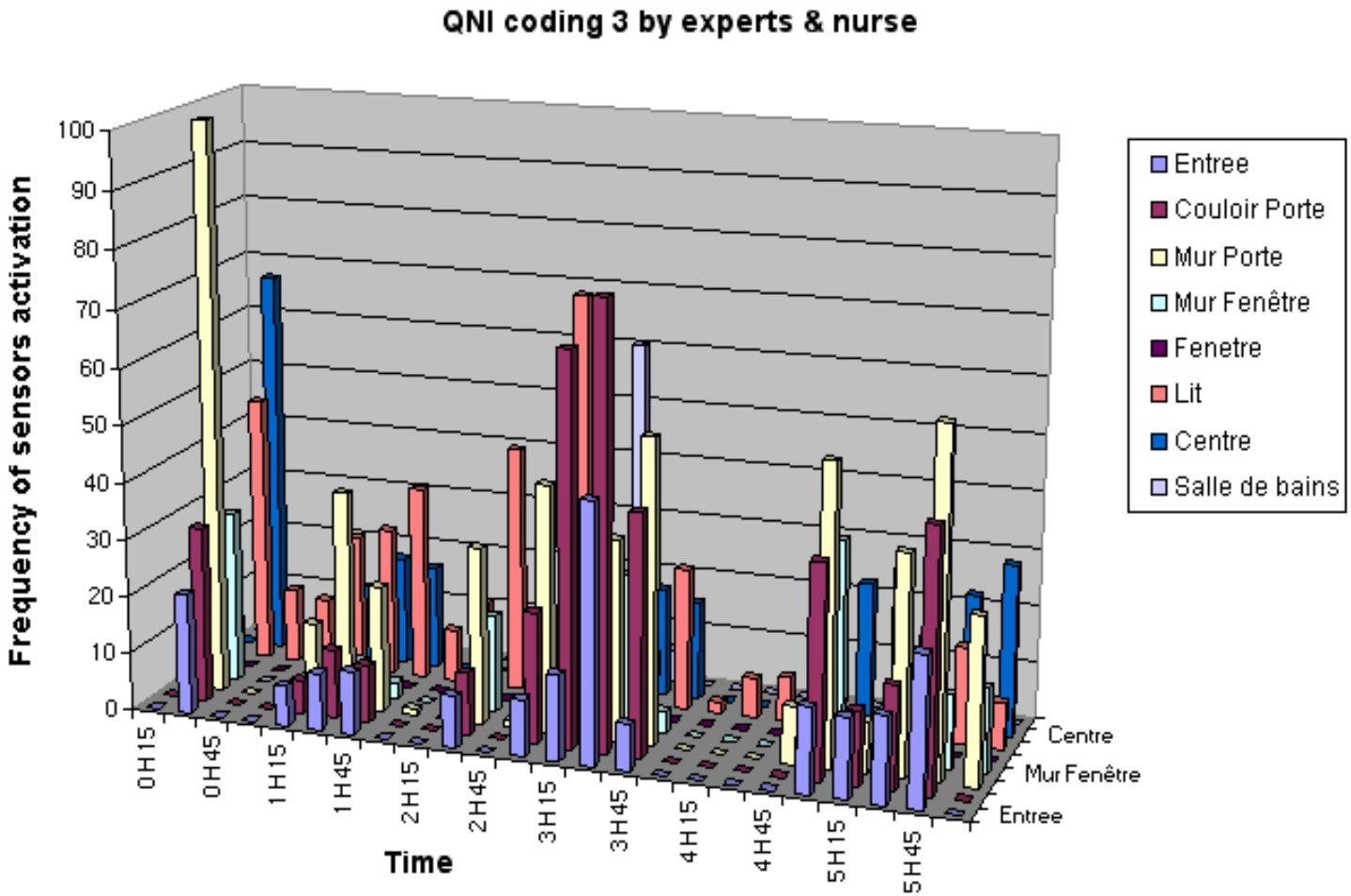
QNI score 1


QNI coding 1 by experts & nurse
Frequency of sensors activation
100
90
80
70
60
50
40
30
20
10
0
0H15
0H45
1H15
1H45
2H15
2H45
3H15
3H45
4H15
4H45
5H15
5H45
Time
Centre
Mur Fenêtre
Entree
Entree
Couloir Porte
Mur Porte
Mur Fenêtre
Fenetre
Lit
Centre
Salle de bains

QNI score 2


QNI coding 2 by experts & nurse
Frequency of sensors activation
100
90
80
70
60
50
40
30
20
10
0
0H15
0H45
1H15
1H45
2H15
2H45
3H15
3H45
4H15
4H45
5H15
5H45
Time
Centre
Mur Fenêtre
Entree
Entree
Couloir Porte
Mur Porte
Mur Fenêtre
Fenetre
Lit
Centre
Salle de bains
Zone de traçage

QNI score 3 : nocturnal agitation



QNI : Experts

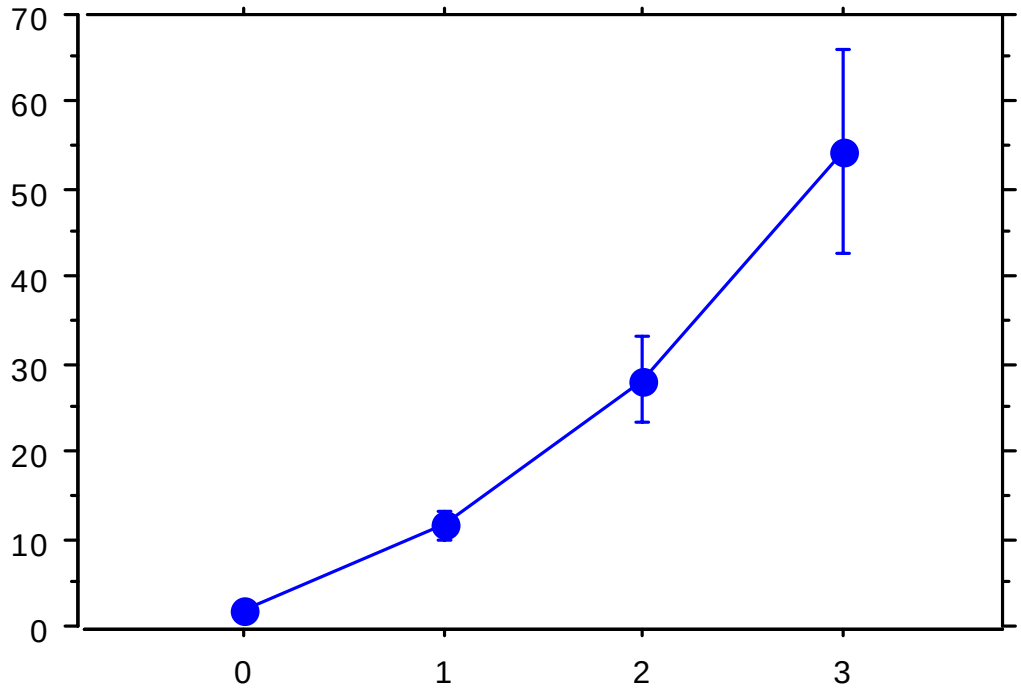


Figure shows the different **QNI scores** (**X-axis**) by *experts* against the *mean* duration of total nocturnal activity (min.) (**Y-axis**) (00:00 – 06:00); $p < 0.01$

QNI : Night staffs

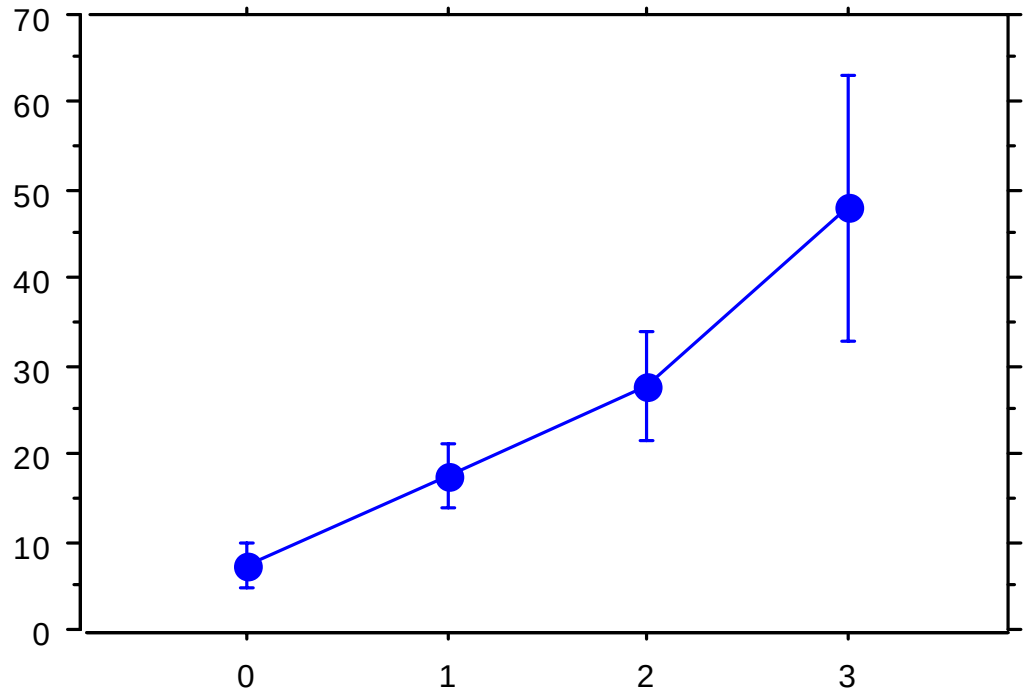


Figure shows the different **QNI scores** (**X-axis**) by *night staffs* against the *mean* duration of total nocturnal activity (min.) (**Y-axis**) (00:00 – 06:00); $p < 0.01$

Predictive factors of nocturnal activity

Predictive factors of the mean nocturnal activity (1)

Nocturnal activity (00:00 – 06:00) (min.)			
Mean (SD)	**Control group (MMS ≥ 25)**	**Cognitive impairment group (MMS < 25)**	**p**
Total activity	4.9 (3.3)	22.0 (21.3)	0.01
Bed activity	2.1 (2.2)	9.5 (15.5)	ns
Toilet activity	1.2 (1.7)	4.2 (4.9)	ns
Room activity	1.6 (2.4)	7.9 (7.5)	0.01

Predictive factors of the mean nocturnal activity (2)

- As there were not significant differences between these 2 groups concerning several parameters (*e.g.*, age, gender, ADL, IADL, MNA, GDS, NPI_{doctor} (sub-score), $CMAI_{nurse}$, prosthesis, hypnotics-sedatives, extrapyramidal signs, …), we pooled patients of both groups and studied the relation : *total nocturnal activity after midnight* versus each of these parameters (Lemke et al. 1999)
- Confidence level (alpha) = 0.005 was chosen (Hilten et al. 1993), given the no. of comparisons a posteriori
- For each parameter, we also checked the absence of significant difference in the MMS scores in the 2 groups (= controlling for the 'effect of cognition')

Predictive factors of the mean nocturnal activity (3)

- The NPI_{doctor} (sub-score) showed a significant association with total nocturnal activity after midnight (p = 0.005)
- The NPI_{doctor} (sub-score) is defined by the presence of at least one of the 3 features : agitation / aggressiveness, abnormal motor behaviour, sleep disturbances
- Total nocturnal activity (min.) after midnight in the group 'present' = 21.9 (19.7) and in the group 'absent' = 6.3 (7.8)
- There was no significant difference between the MMS scores in the 2 groups (*i.e.*, present / absent)
- There was no interaction between the MMS score and NPI_{doctor} (sub-score)

Predictive factors of the variability of nocturnal activity

Patient characteristics	Spearman's ρ	p
MMS (n = 27)	-0.57	< 0.001
ADL (n = 27)	-0.56	< 0.001
NPI_{doctor} (global score) (n = 19)[#]	0.71	< 0.001

Parameters : MNA, IADL, GDS, $CMAI_{nurses}$, height, weight, age, gender, Waterlow's score, prosthesis, extrapyramidal signs, hypnotics-sedatives did not show an association at confidence level = 0.005

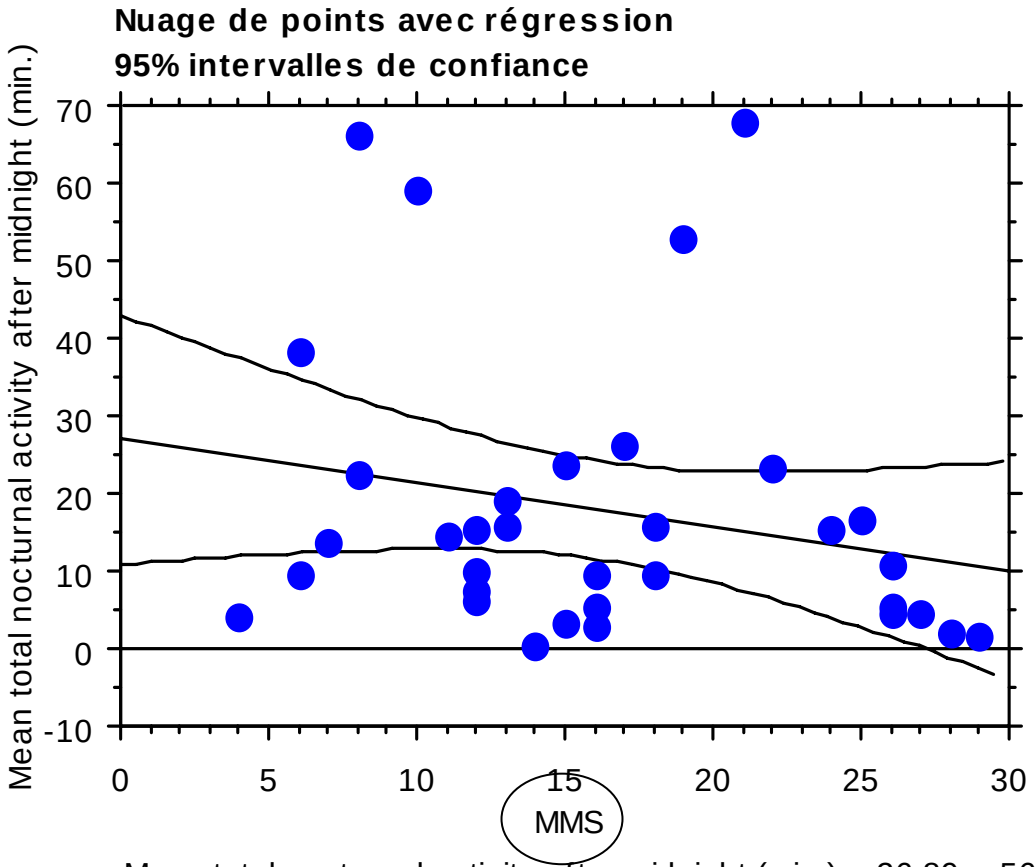
[#] NPI (global score) = sum of (frequency x gravity) scores

Comparison of the level of activity during day and night

Mean total activity (min.)	Control group (N = 6)#	Cognitive impairment group (N = 21)#	p
22 hours (10:00 – 08:00)	105.4 (63.4)	140.0 (61.3)	ns
Day (10:00 – 21:00)	86.2 (49.8)	90.9 (39.1)	ns
Night (21:00 – 08:00)	19.2 (16.8)	49.1 (32.9)	0.02
After midnight (00:00 – 06:00)	4.9 (3.3)	22.3 (19.7)	< 0.01

Mean (SD)

Scatter plot showing the absence of correlation between cognitive decline and nocturnal activity



Predictive factors of mean nocturnal activity : regression model

- Multiple linear regression model :
  - Mean total nocturnal activity after midnight (min.) = 101.1 – 2.1(Waterlow's score) – 1.8(GDS) – 6.9(ADL)
  - R^2 (adj.) = 0.37; p = 0.01
- Multiple linear regression model in other studies :
  - Hilten et al. (1993) explaining Mean Immobility Period by gender and hypnotics use; R^2 = 0.47
  - Kronholm et al. (1993) explaining (in non-elderly subjects) nocturnal activity by psychological distress, problem of respiration, blood glucose, sympathetic activity level; R^2 = 0.26

Is it possible to categorise the 'demented' patients as normo-, hypo-, or hyper-active in the night ? (1)

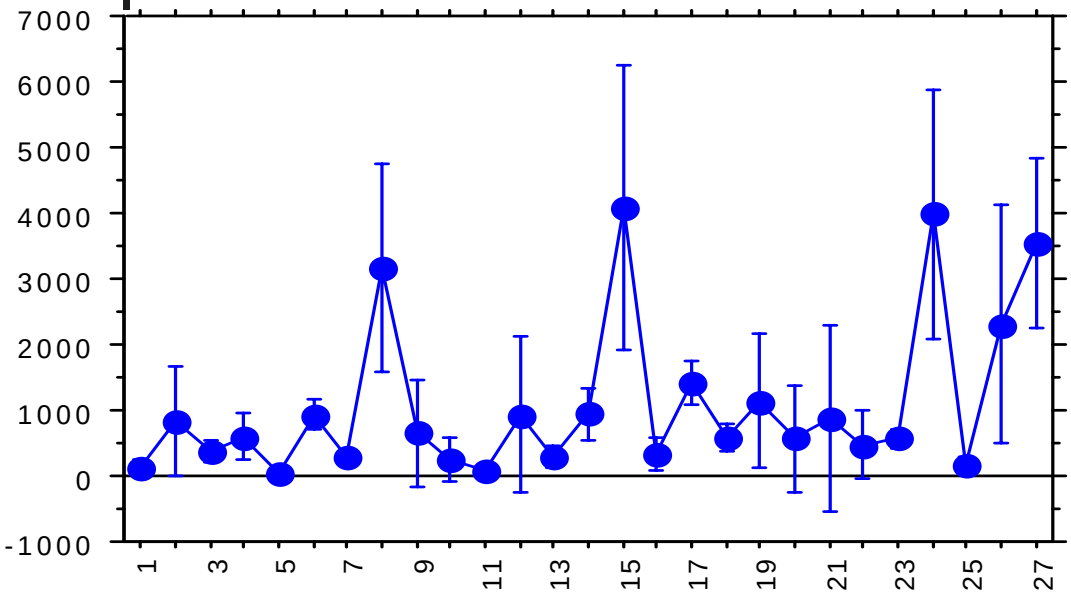


Figure shows the *mean* duration of total nocturnal activity (00:00 – 06:00) in **secondes** (**Y-axis**) of 27 **patients** (**X-axis**). The control group patients represent no. 1, 7, 9, 11, 13, 16

For the 'cognitive impairment' patients, by taking the values of the mean total nocturnal activity within the 10^{th}-90^{th} percentile, there are 4 patients above upper limit. They are numbered in the figure as : 8, 15, 24, 27 → excluded

Is it possible to categorise the 'demented' patients as normo-, hypo-, or hyper-active in the night ? (2)

- The 4 'outliers' were excluded → clinically 'acute confusional state or delirium'
- For the 17 patients of the cognitive impairment group, we calculated μ ± 3 SE
- Method analogic to the Control Charts
- 6.3 min. – 19.2 min. [Upper control limit - Lower control limit]
- 4 patients hypo-, 2 patients hyper- et 11 patients normo-active

Impact of the Gardien system on the patients and their family

[Banerjee et al. 2006 (in press)]

- Development of a mini-questionnaire concerning the acceptability of the system :
  - A score -5 signifies that it is not at all acceptable
  - A score 5 signifies that it is very much acceptable
- The mean score was 2.2 in the controls and 1.8 in the cognitive impairment group
- The mean score was 4.7 for the family of the controls and 4.6 for the family of the cognitive impairment group
- The internal consistency (Cronbach's alpha) of the mini-questionnaire was 0.3 for the family and 0.7 for the patients

Modelling of the nocturnal activity

Modelling of nocturnal activity in some other studies

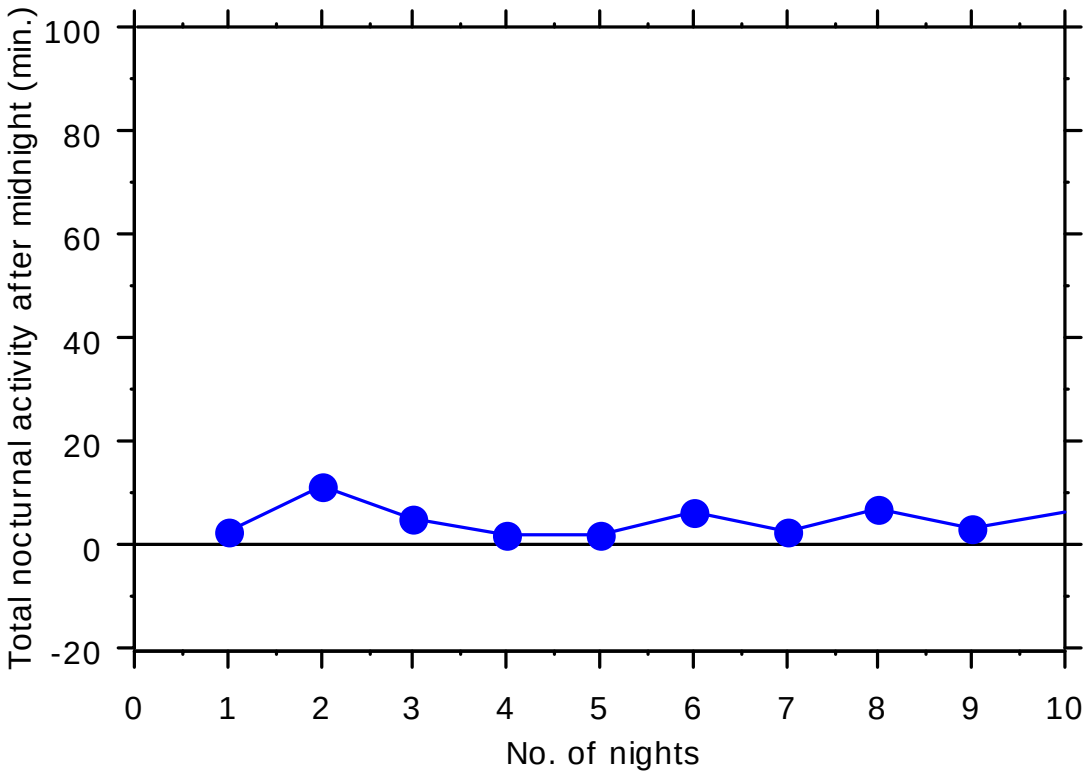
1. Satlin et al. (1991) – 19 Alzheimer patients classified empirically by bracelet actimetry as :
   - Pacers : who moved non-stop
   - Non-pacers : who did not move much
2. Honma et al. (1998) – a case report on 8 hospitalised dementia patients by bracelet actimetry as :
   - Type A : nocturnal confusion
   - Type B : wandering
   - Type C : hypobulia
   - Type D : lying down type

Modelling of nocturnal activity

(Banerjee et al. 2004, 2005)

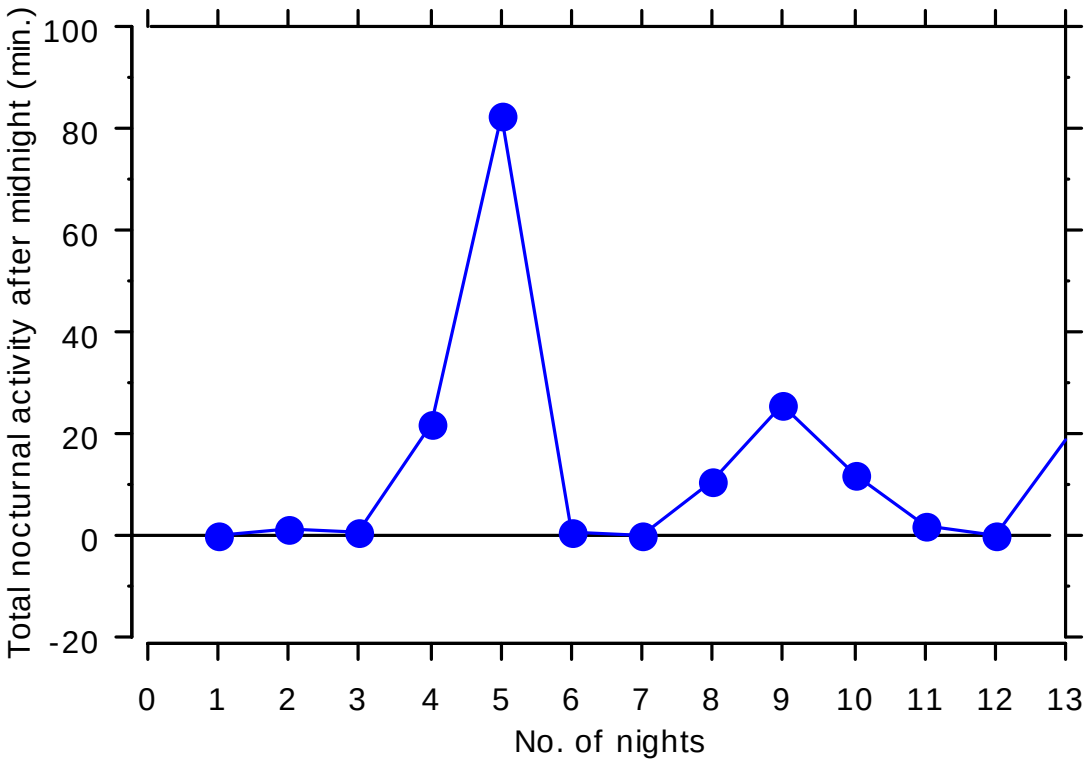
- Actimetric parameters specific for each group :
  - ***Median*** nocturnal activity (after midnight) over 7 nights
  - ***Standard deviation*** of nocturnal activity during their full stay period
- Compared with the **reference method** = median QNI score **by experts** over 7 nights (→ Integer number)

Model : Stable



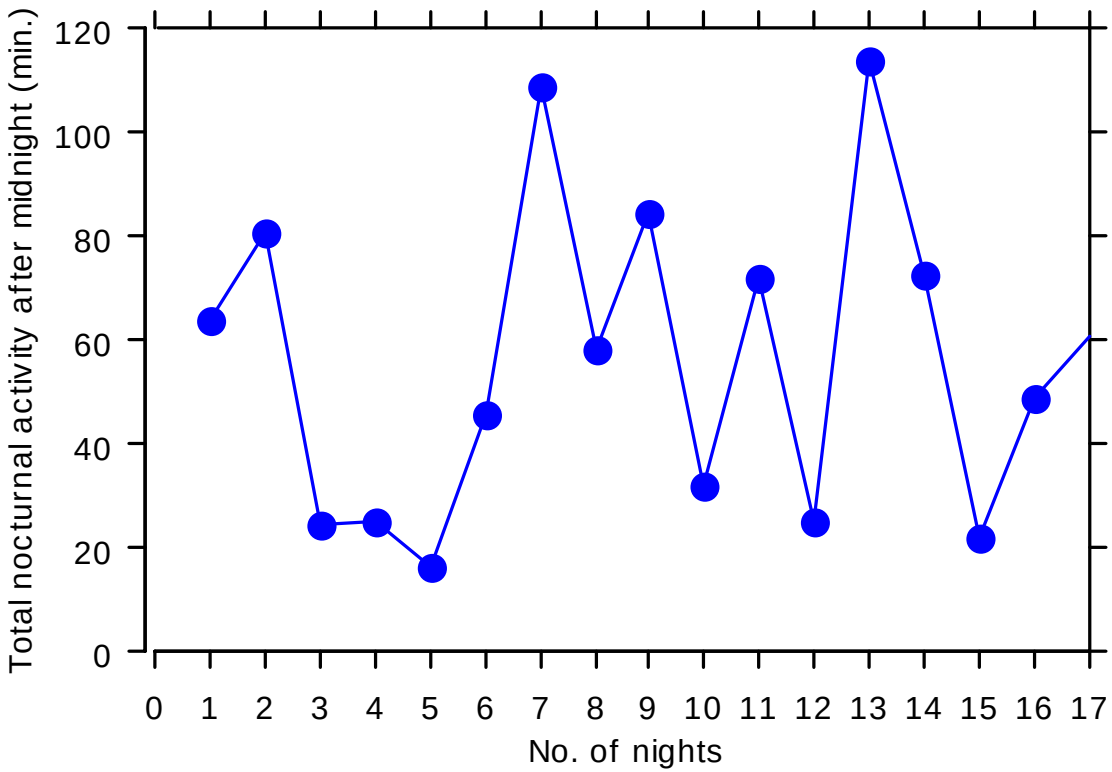
- Median and variability of nocturnal activity = low
- Median QNI score by experts = 0 or 1
- Never have been scored QNI = 3 during their entire period of stay
- May have been scored QNI = 2 for one or more nights

Model : Acute paroxysmal nocturnal agitation



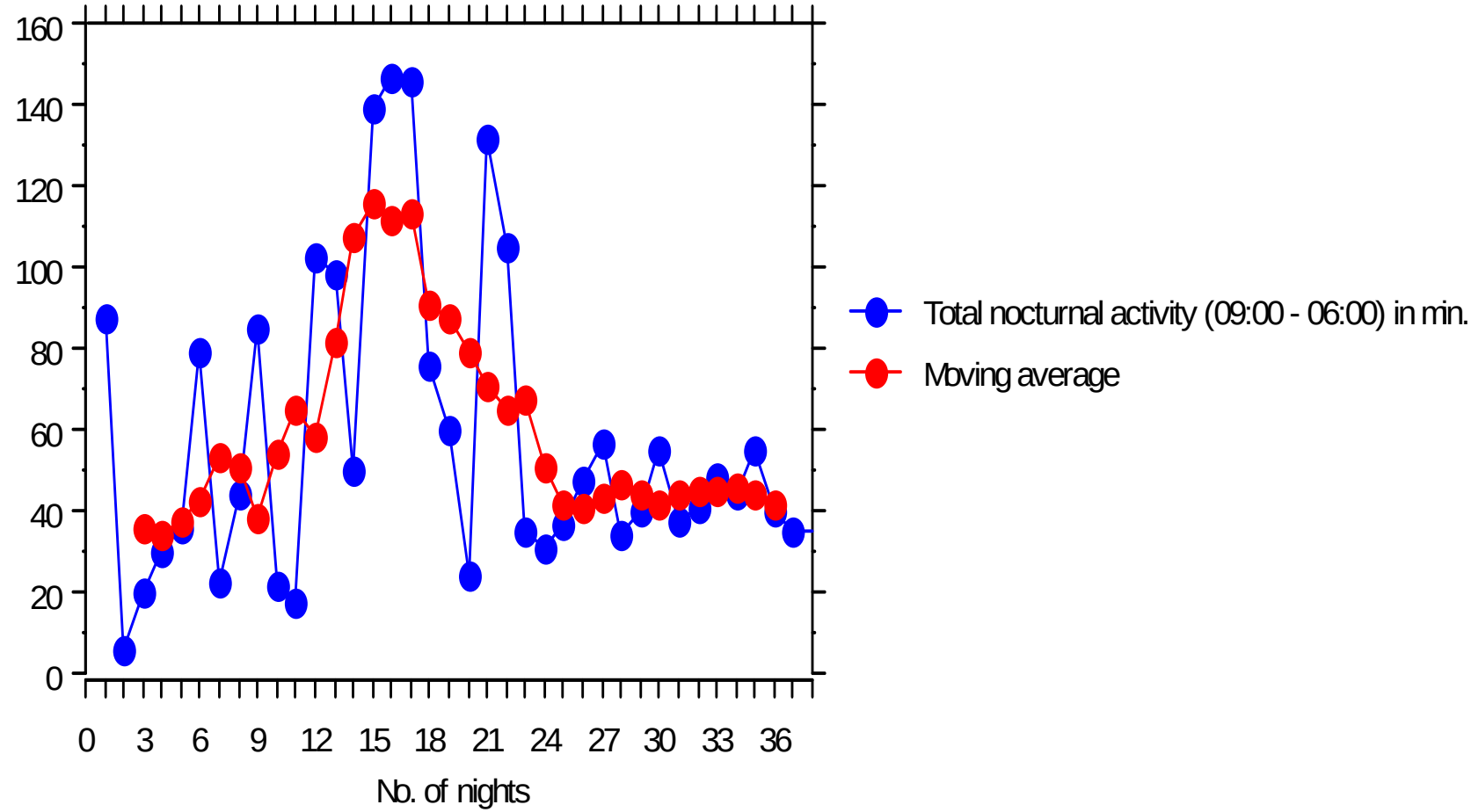
- Median nocturnal activity = low, but variability = high
- Median QNI score by experts = 0 or 1
- At least once scored QNI = 3 during their full stay period, signifying nocturnal hyperactivity whose cause could not be identified

Model : Chronic nocturnal hyperactivity



- Median nocturnal activity = high, and variability = usually high
- Median QNI score by experts = 2 or 3
- Might not have been scored QNI = 3 for even one nuit during their full stay period

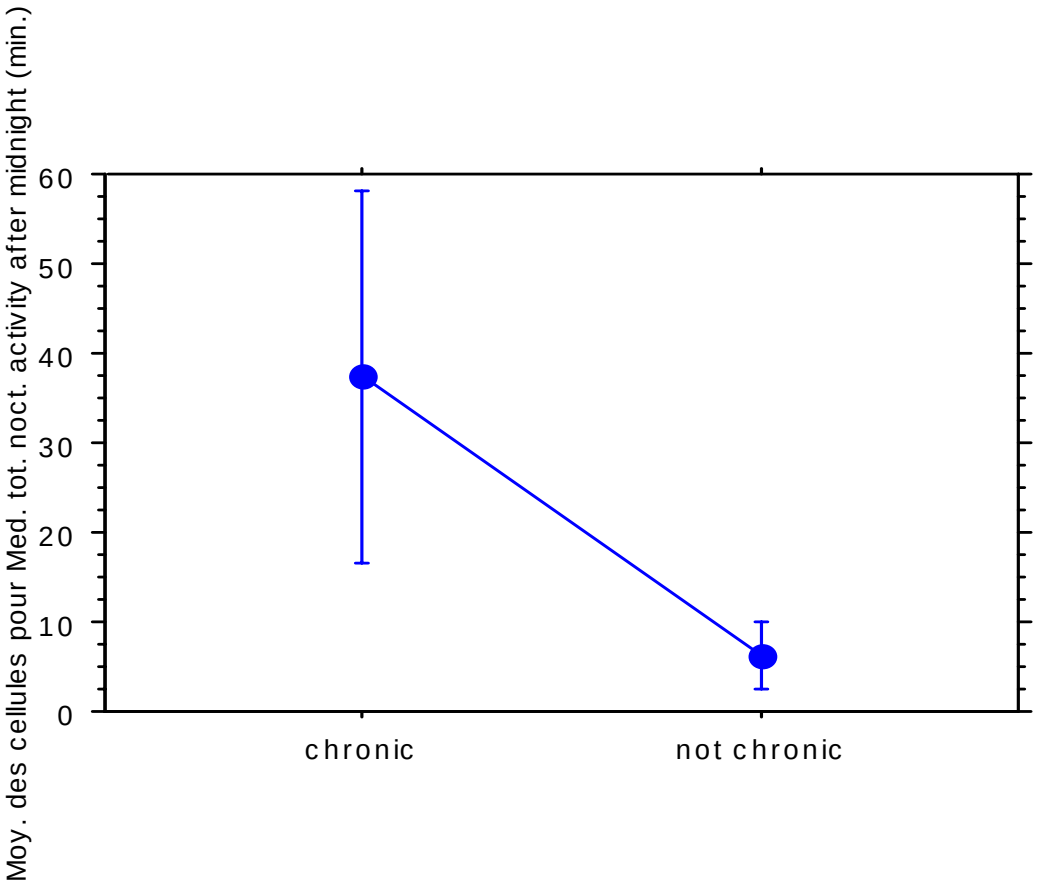
Model : Acute-on-chronic nocturnal agitation



Types of actimetric models observed

- Stable (12 patients, of which 6 controls)
- Pathologic models :
  - Acute paroxysmal nocturnal agitation (7 patients)
  - Chronic nocturnal hyperactivity (8 patients)
  - *Acute-on-chronic nocturnal agitation (1 patient in the pilot study phase)*

Determination of the cut-off value for the median nocturnal activity

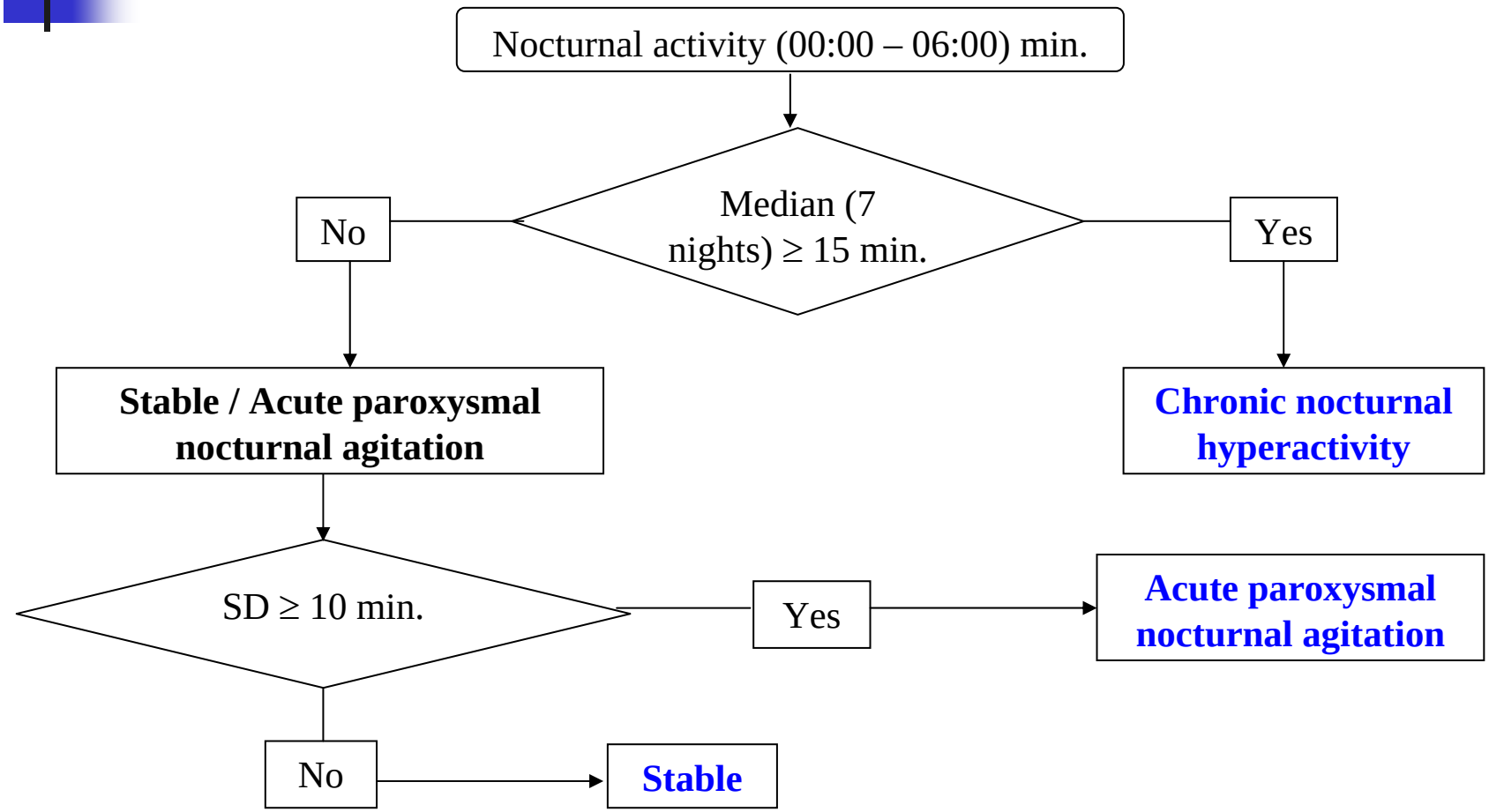


- Figure compares the means of the median nocturnal activity after midnight (min.)
- Group 'chronic' consists of patients having median QNI scores = 2, 3 by experts
- Group 'not chronic' consists of patients having median QNI scores = 0, 1 by experts
- $p < 0.01$

Why use a cut-off value for the variability of nocturnal activity ?

- In order to distinguish the stable group from the acute paroxysmal nocturnal agitation group
- We chose an arbitrary value of 10 min. as the cut-off value
- SD ≥ 10 minutes means variability high and SD < 10 minutes means variability low
- 2 x 2 contingency table (Fisher's exact test)
- $p < 0.01$

Validation of actimetric models : flowchart



Predictive factors of mean nocturnal activity : logistic regression

- Based on the cut-off value of 15 minutes, we tried to predict the patiens having nocturnal activity high from the patients having nocturnal activity low
- Logistic regression model :
  - Waterlow's score → OR = e^{β} = 10.9 (1.2 – 103.0, 95% CI); p = 0.04
  - Median QNI score (over 7 nights) by *nurses* → OR = e^{β} = 7.2 (0.9 – 59.5, 95% CI); p = 0.07

Development of a teleassistance system for the automatic detection of nocturnal hyperactivity

Introduction to the frequency analysis

- Recapitulation :
  - 'Resolution' of the actigramme = 15 minutes
  - Within a 15-minute epoch interval, it sums the no. of activations (or changes of state) of each sensor
- Sign function is given by :

  $f(x) = -1$ if $x < 0$,
  $= 0$ if $x = 0$,
  $= 1$ if $x > 0$
- Data transformation of the actigramme for 352 nights to a positive count no. corresponding to the **frequency of displacement** of the patient
- This new transformation was denoted as « frequency function »

An algorithm for the automatic detection of nocturnal hyperactivity

Reference method = analysis by experts, *i.e.*, analysis of the system data

- No. of nights analysed as not agitated = 308 (87.5%) = QNI score {0, 1, or 2}
- No. of nights analysed as agitated = 44 (12.5%) = QNI score 3

Definition of sensitivity and specificity

- Sensitivity - the *capacity* to detect a nocturnal agitation by the system, when that was also considered as nocturnal agitation by the method of reference (experts or nurses)
- Specificity - the *capacity* to detect a non-agitated night by the system, when that was also considered as non-agitated night by the method of reference (experts or nurses)

Preliminary trials with different algorithms

- Night / day ratio : lack of specificity
- Percentile method : lack of sensitivity and specificity
- Standardised variable : sensitivity and specificity vary according to the variability of nocturnal activity in the patient

Further trials with algorithms

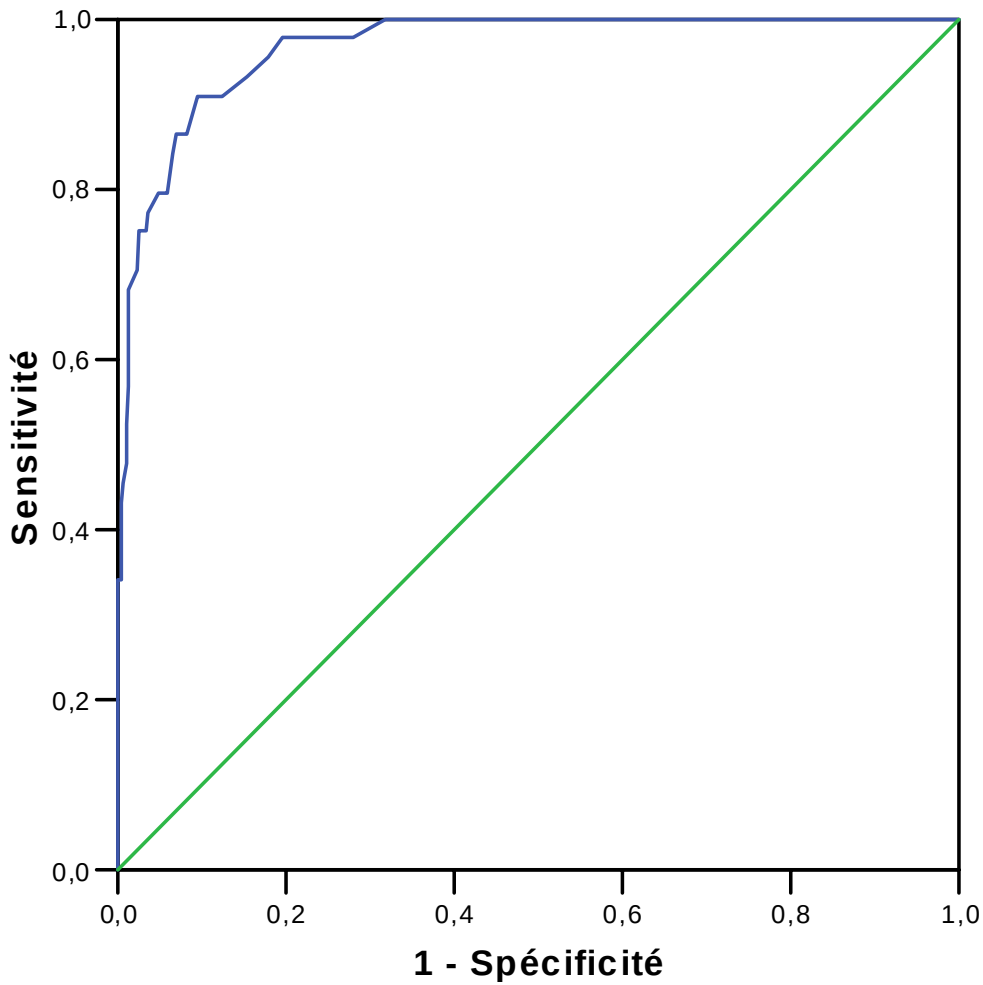
- Duration (minutes)
- Moving median filter (7 nights) : not sensitive for the patients of the type : chronic nocturnal hyperactivity
  - We tried to separate this group by the threshold value of 15 minutes and then apply this algorithm only on the ‘stable’ or ‘acute paroxysmal nocturnal agitation’ patients
- Sensor count
- Frequency function

Comparison of ROC curves for the different methods

Algorithm	Evaluation by experts*	Evaluation by nurses*	p
Duration (352 nights)	0.88 (0.04)	0.85 (0.06)	ns
Moving median filter (298 nights)	0.74 (0.10)	0.84 (0.11)	ns
Sensor count (352 nights)	0.91 (0.04)	0.82 (0.08)	ns
Frequency function (352 nights)	0.97 (0.02)	0.79 (0.08)	< 0.01

* ROC curve area (95% CI)

ROC curve : frequency function (evaluation by experts)



Validation of this algorithm

- Create an experimental group (N = 178) and a validation group (N = 174) by random allocation of nights in the 2 groups
- Test the null hypothesis :
  - H_0 = proportion of agitated nights is equal in these 2 groups
  - χ^2-test; $p = 0.06$
- Find an optimum threshold value in the experimental group (= 31.5) from the ROC curve of 178 nights
- Apply this value on the validation group to establish the sensitivity and specificity of this algorithm

Validation of this algorithm : results

- ROC curve areas :
  - Experimental group = 0.96 (± 0.04, 95% CI)
  - Validation group = 0.97 (± 0.02, 95% CI)
- By taking the optimum threshold value from the experimental group and applying it on the validation group, we get :
  - Sensitivity = 89.3%
  - Specificity = 89.7%
  - Youden's index (sensitivity + specificity – 1) = 0.79
  - Positive predictive value = 62.5%
  - Negative predictive value = 97.8%

What values to be used by the system ?

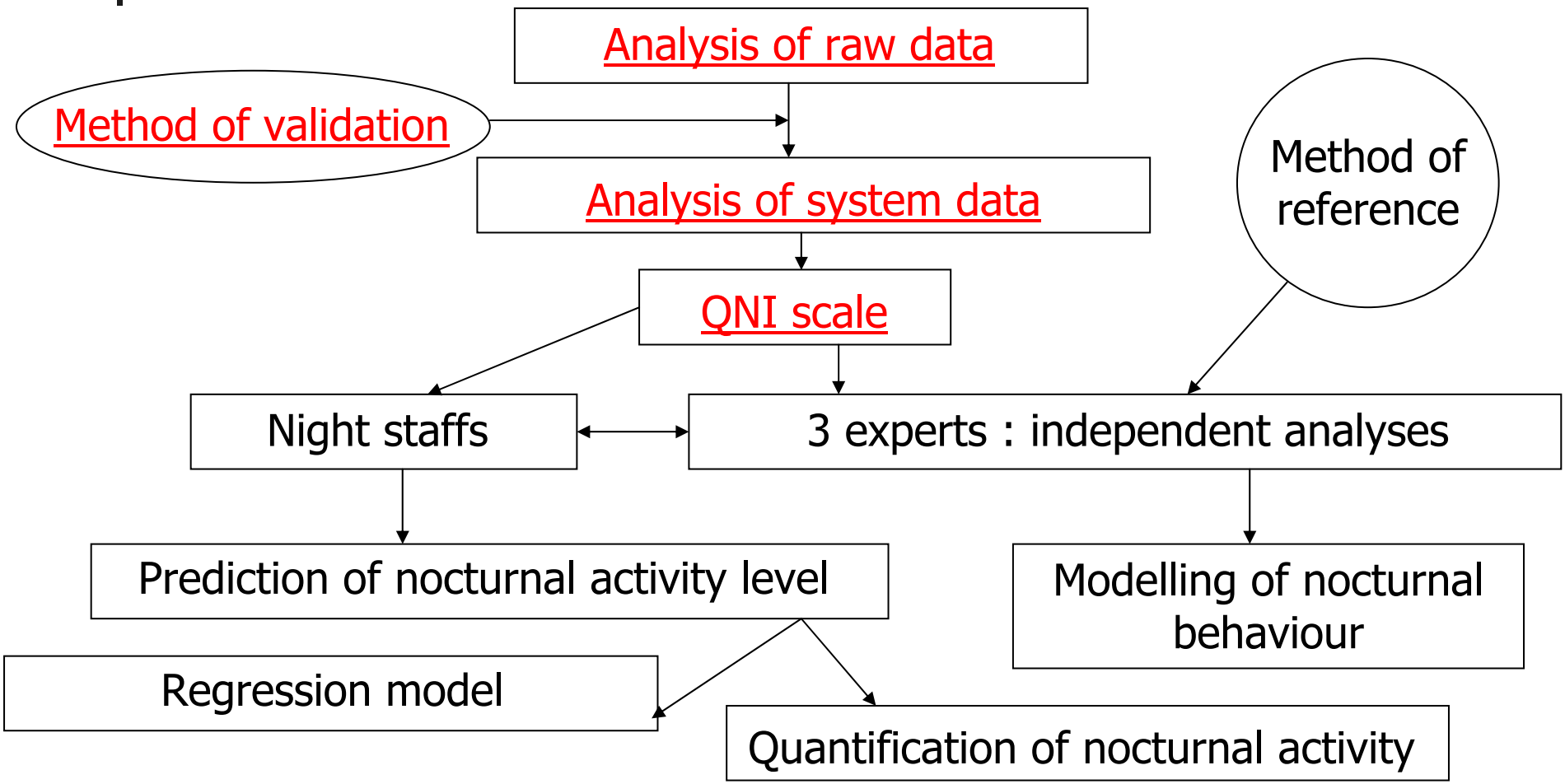
Cut-off values of the system :

- Frequency function value ≤ 20 = normal night
- Frequency function value 21 – 31 = moderate nocturnal activity
- Frequency function value 32 – 50 = nocturnal agitation
- Frequency function value ≥ 51 = severe nocturnal agitation

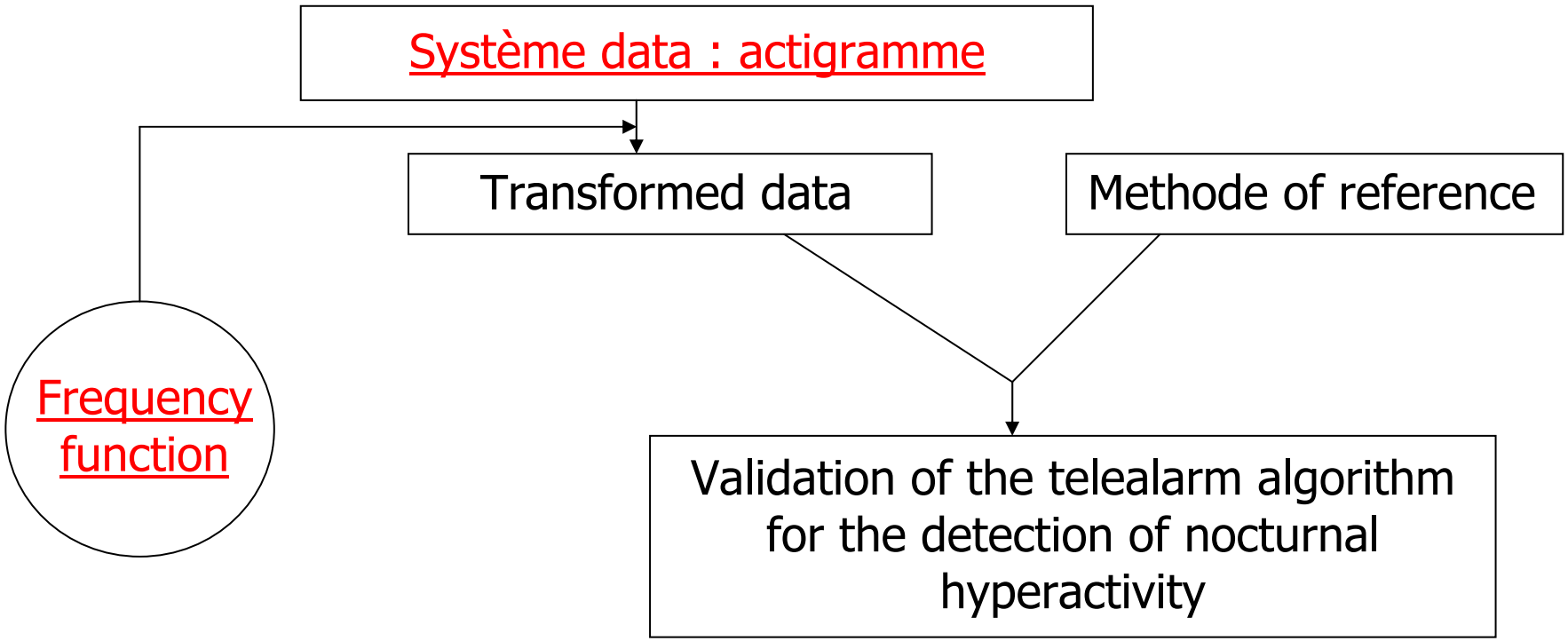
It is possible to define a cut-off value for the nocturnal hypoactivity ?

- There were 6 nights (1.7%), where the value of frequency function = zero
- There were 43 nights (12.2%), where the total duration of displacements after midnight = zero
- For this reason, it is probably prudent not to propose an alarm for nocturnal hypoactivity with current settings of the system

Synthesis of data analysis (1)



Synthesis of data analysis (2)



Improvements of Gardien in the future

- One single software for several rooms
- Functioning 24/24 hours
- Equipped with wireless system
- Capable of adding several days', nights' actigrammes
- Capable of drawing activity curves over several days, nights
- Calculate the time elapsed when the patient is outside the room
- Integration of a telealarm based on frequency function to signal nocturnal hyperactivity

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Scheme of presentation

- Introduction of the subject
- Purpose of the study
- Introduction to ‘Gardien’
- Methodology
- Results
- Discussion
- Conclusion

Discussion (1)

- Body-worn or remote actimetry ?
- How many nights to be observed ?
- In the hospitalised elderly, does it exist an intra-subject stability of nocturnal activity ?
- In addition, does it exist an intra-group stability of nocturnal activity ?

Discussion (2)

- Is the system sensitive enough to detect fine bed movements ?
- Why should the system have a high negative predictive value in not detecting nocturnal hyperactivity ?
- Does the system yield an advantage over the nurses concerning the detection of nocturnal hyperactivity ?

Scheme of presentation

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Conclusion

- Description and development of the Gardien system
- Analysis and interpretation of patient data
- Modelling of nocturnal behaviour
- Aid to automatic detection of nocturnal hyperactivity in elderly hospitalised patients
- Assessment of acceptability of the system

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