British Heart Foundation
Health Promotion Research Group

UNIVERSITY OF OXFORD

Using wearable image sensing to measure physical activity & sedentary behavior

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3rd March 2011 – EPARC & CWPHS, San Diego

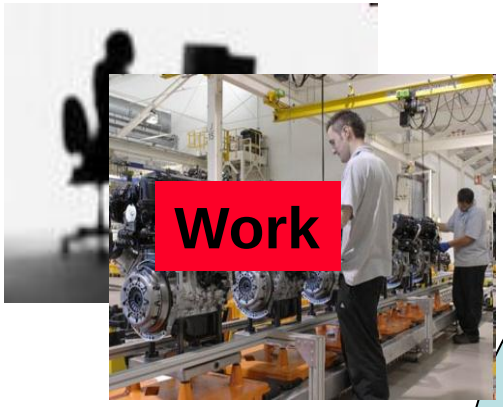
International consensus on health benefits of physical activity

- Physical activity can reduce the risk of:
  - Cardiovascular disease
  - Hypertension
  - Obesity
  - Some forms of cancers
  - Non insulin-dependent diabetes mellitus
  - Strokes
  - Osteoarthritis, by maintaining normal muscle strength, joint structure and joint function
  - Osteoporosis

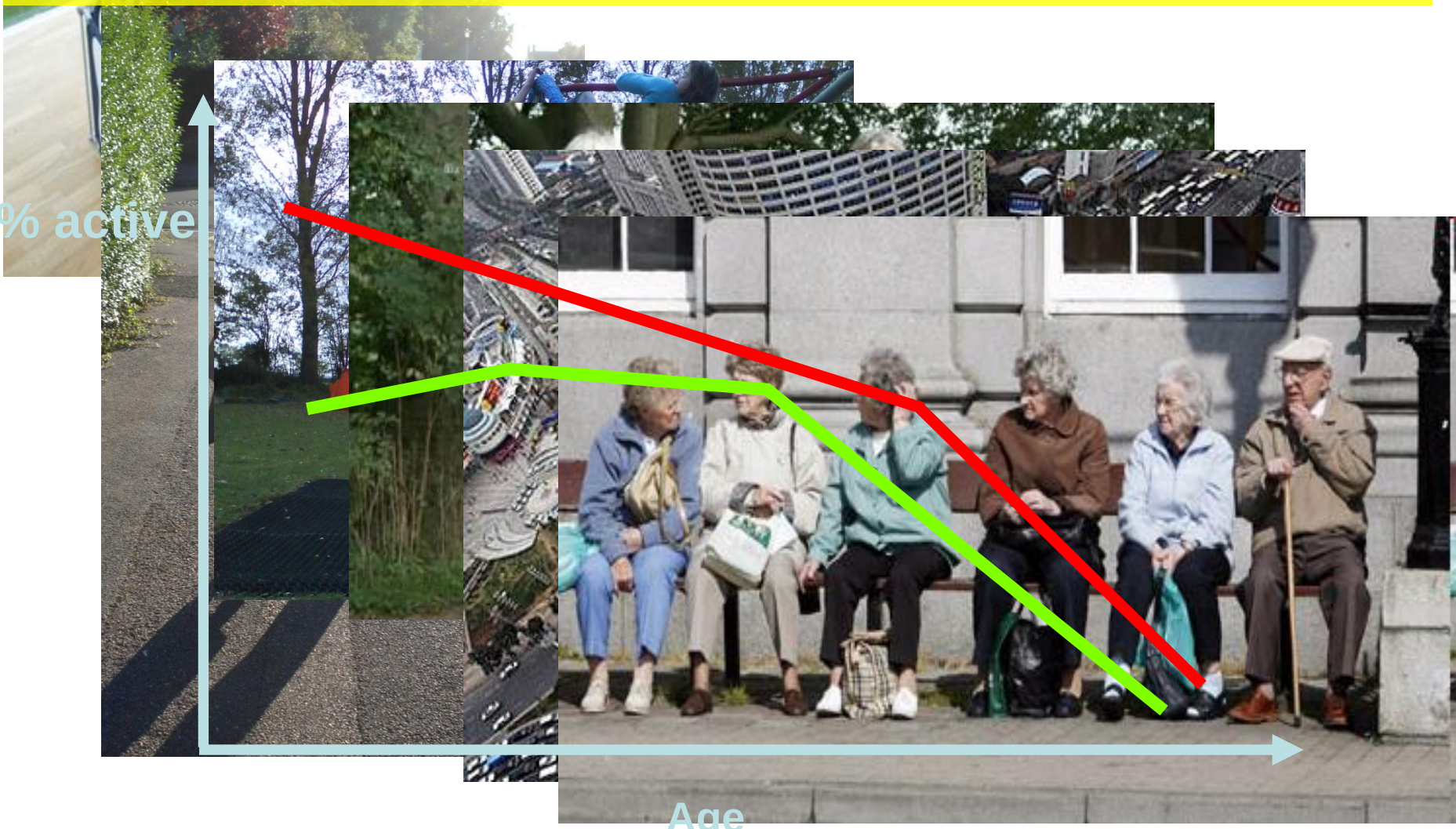
- Cognitive function
- Crime reduction and community safety
- Economic impact and regeneration of communities
- Education and lifelong learning
- Psychological well-being
- Self esteem
- Management of anxiety and depression
- Social capital and community cohesion
- Drug misuse
- Carbon use

(US Dept Health & Human Sciences, 1996; U.K. CMO, 2004; Sport England, 2009)

Physical activity

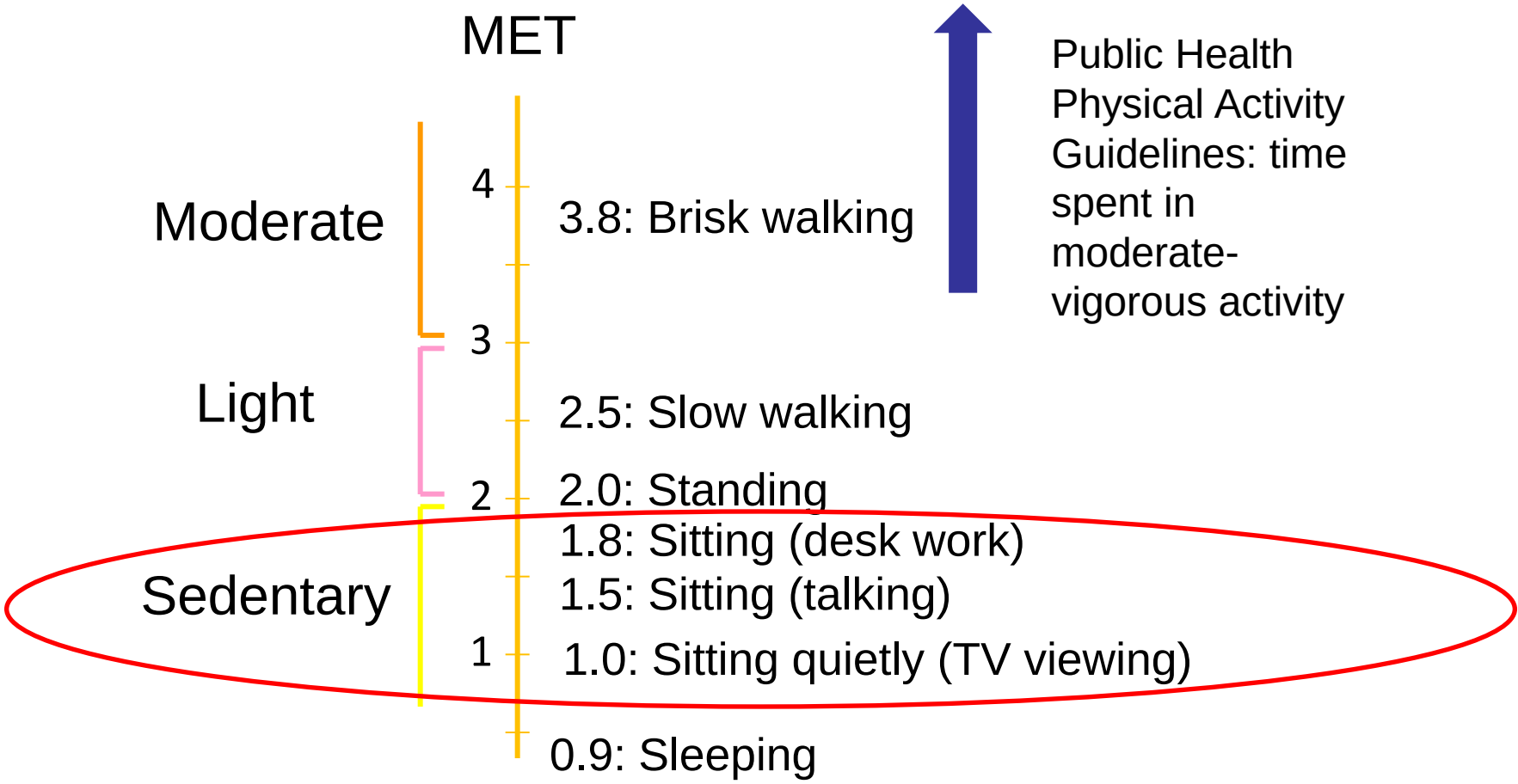


61% of men and 71% of women do not meet the U.K. Chief Medical Officer's minimum recommendations for physical activity in adults



Sedentary Behaviour

Sitting (or lying down), involving < 2 MET (metabolic equivalent)



Ainsworth BE, et al. Med Sci Sport Exer. 2000;32:S498–S516

Our modern ‘sitting-oriented’ society

Awake
7 am

Transport to work
45 mins

Breakfast
15 mins

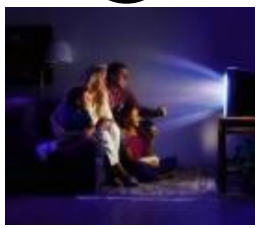
Work on computer
3.5 hrs

Lunch
30 mins

Work on computer
4 hrs

Transport From work
45 mins

Evening meal
30 mins



Watch TV
4 hrs

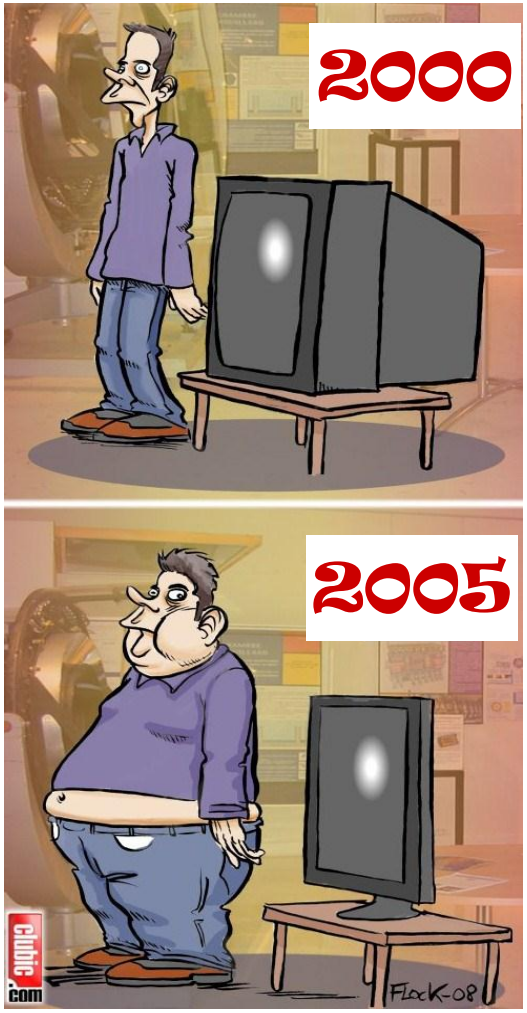
Walk – 30 min

Sleep
11pm

Sitting Opportunities 15.5 hrs

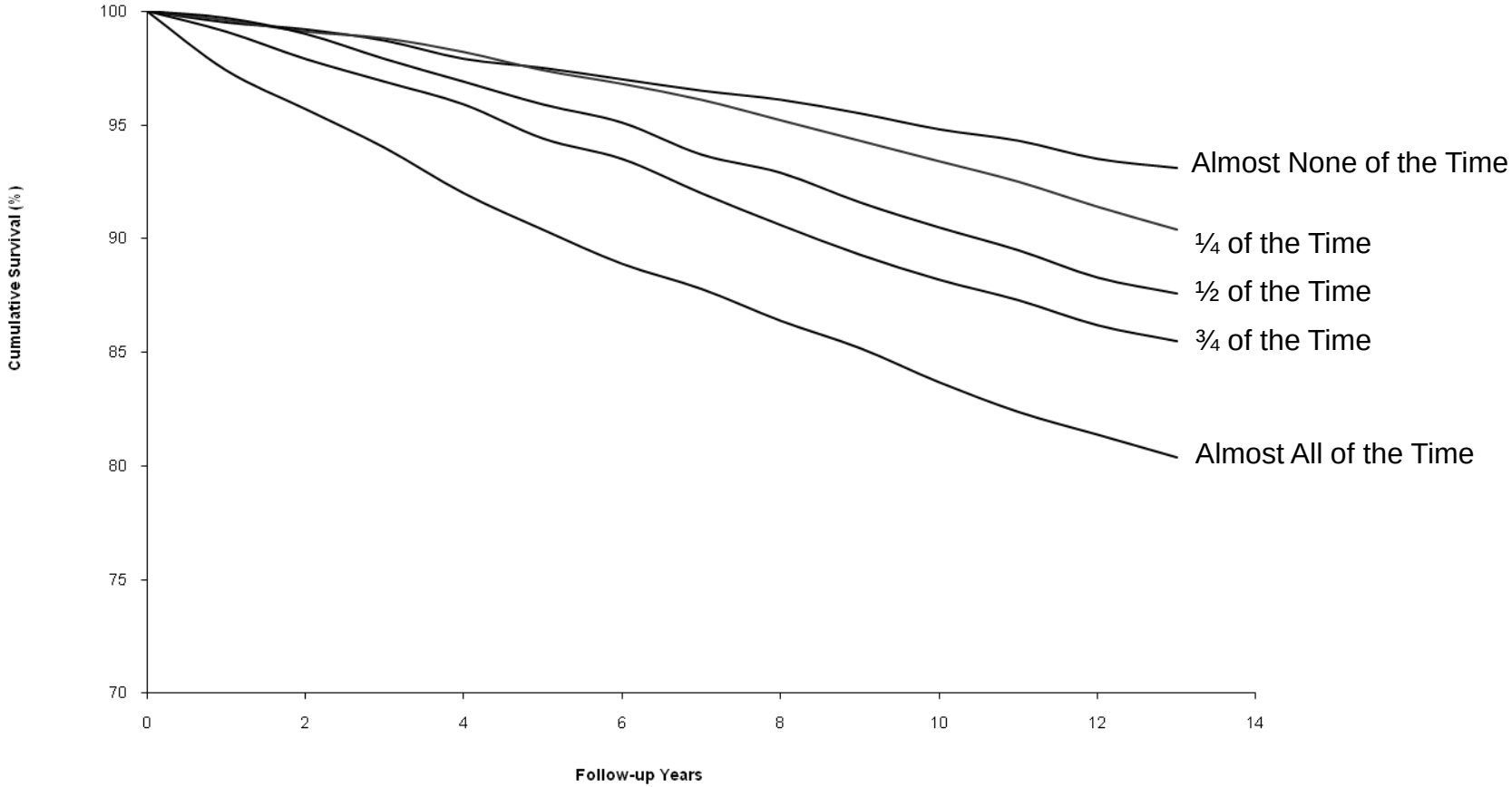
AusDiab: are *5-year changes* in TV viewing time associated with 5-year changes in:

- Overweight (waist circumference) and other metabolic syndrome variables
- → independently of physical activity, diet quality, and other confounding factors
- → in population-based sample of healthy Australian adults (AusDiab)



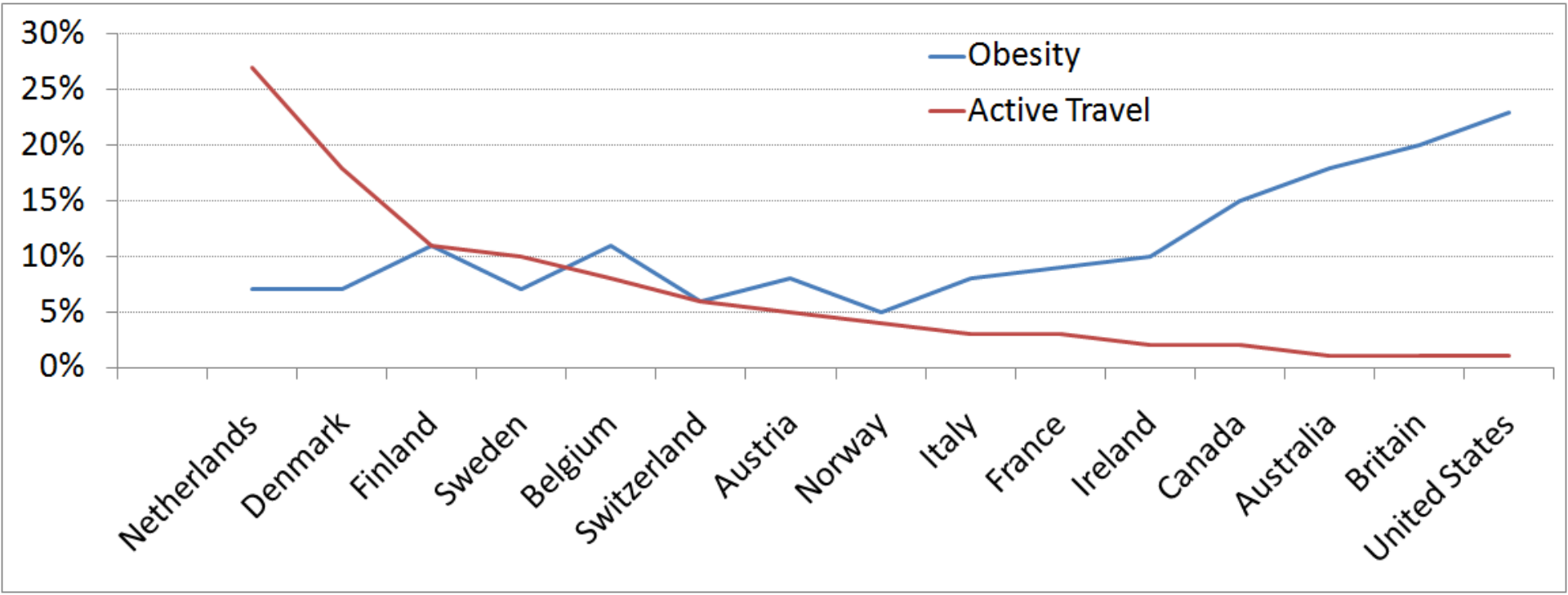
Daily Sitting Time and All-cause Mortality in 17,013 Canadian Men and Women

Canada Fitness Survey 12-year Mortality Follow-up, 1981-1993



Katzmarzyk PT *et al.* (2009) Sitting time and mortality from all causes, cardiovascular disease, and cancer. *Med Sci Sports Exerc* 41: 998-1005

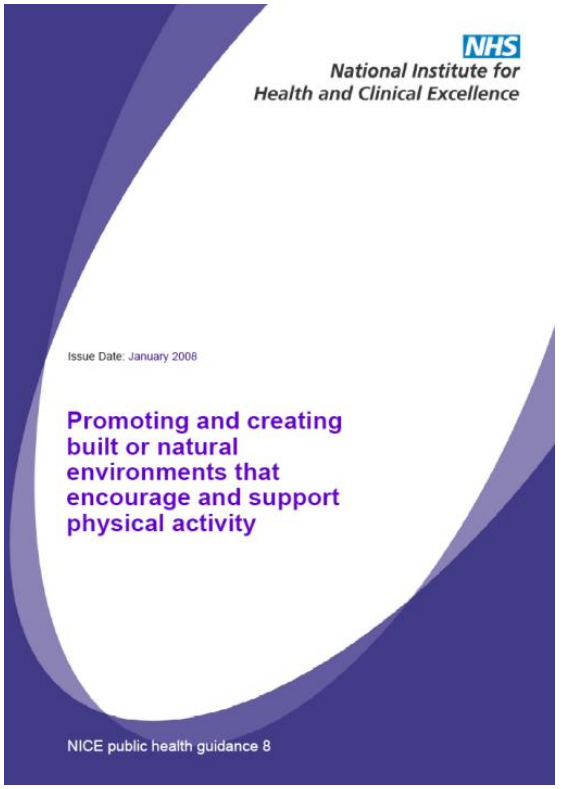
Obesity & Active Travel



From: Pucher & Buehler. Transport Reviews, 2008. OECD (age 15 and over). Data from various sources.

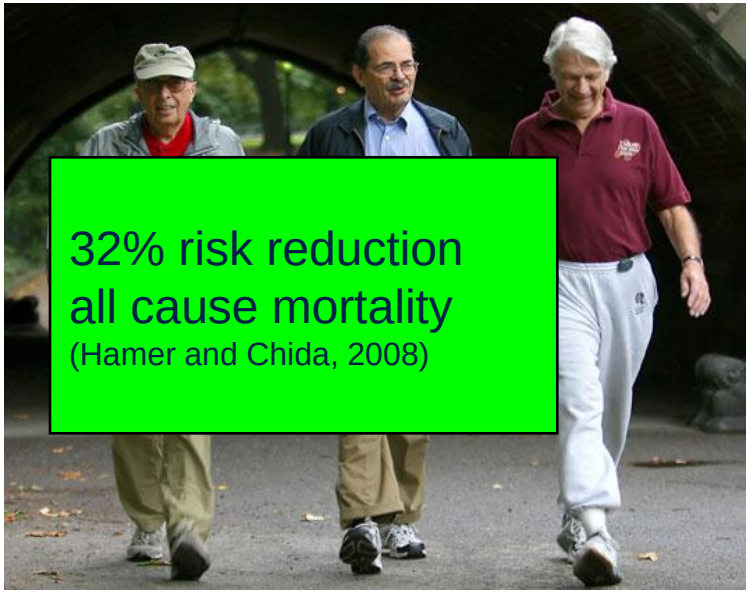
Obesity and active travel

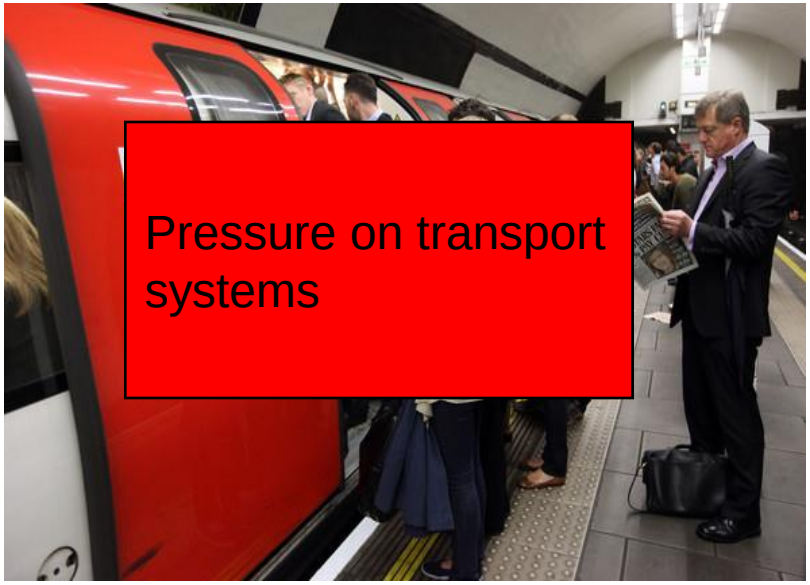
- Each additional kilometre walked per day is associated with a 4.8% reduction in likelihood of obesity
- Each additional hour spent in a car per day associated with a 6% increase in likelihood of obesity.
- Active travel interventions must contain environmental supports to sustain individual choice (i.e. public transport)



Frank, L., et al (2004) *Obesity relationships with community design, physical activity, and time spent in cars*. American Journal of Preventive Medicine, 27(2): 87-96.

NICE review – physical activity and environment

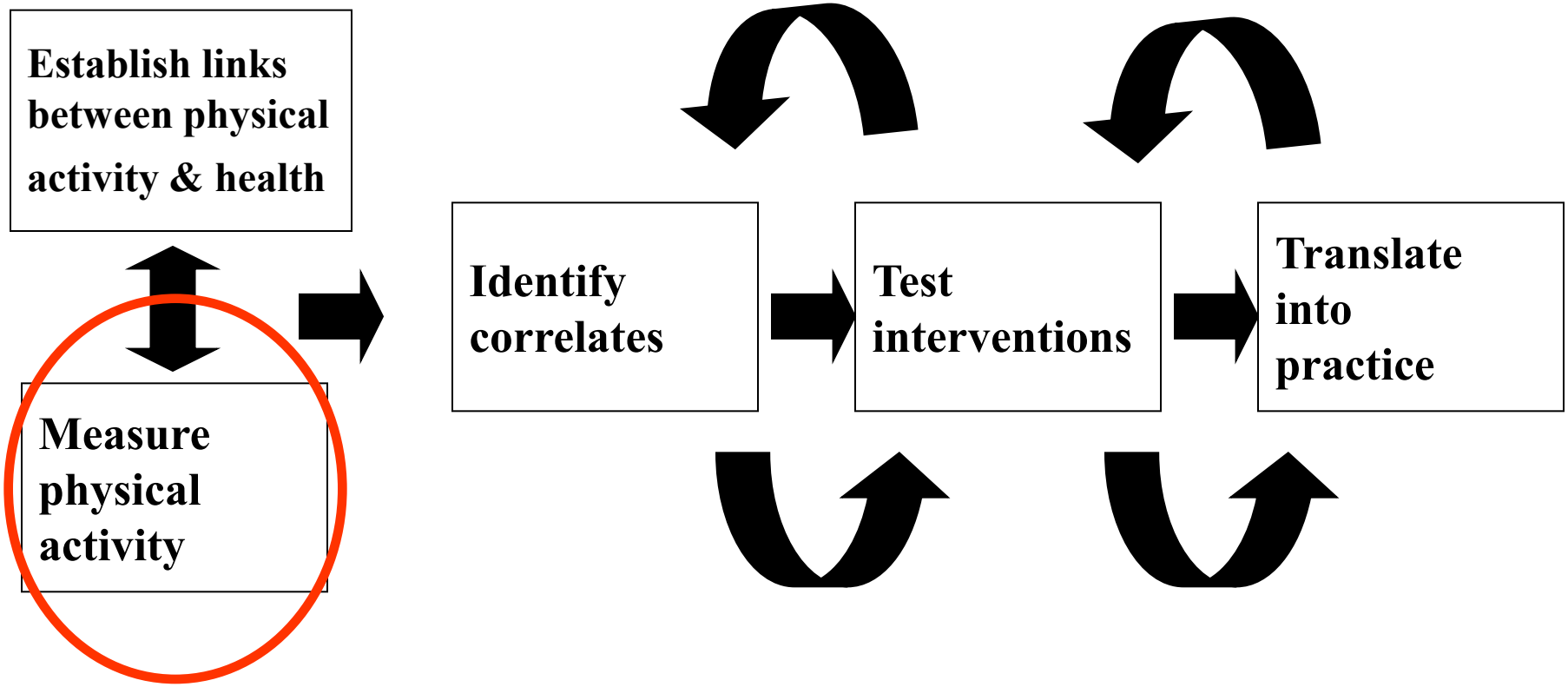

32% risk reduction
all cause mortality
(Hamer and Chida, 2008)


Pressure on transport systems


28% risk reduction
all cause mortality
(Anderson et al, 2000)


Sedentary behaviour
Carbon emissions

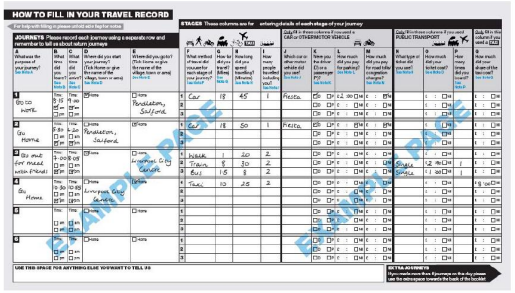
Behavioural epidemiology framework



Sallis and Owen (1999)

Current tools and technologies

Pedometer



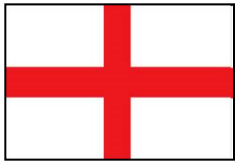
Travel Diary

Accelerometer

GPS tracker

Percentage of adults from same study meeting physical activity recommendations:

NHANES (self report): 50%
Accelerometer: 5%
(Troiano et al, 2009)



Self-report questionnaire: 38%
Accelerometer: 5%
(HSE, 2009)

HOW TO FILL IN YOUR TRAVEL RECORD

For help with filling in please unfold side flap for notes

JOURNEYS Please record each journey using a separate row and remember to tell us about return journeys

STAGES These columns are for entering details of each stage of your journey

Only fill in these columns if you used a CAR or OTHER MOTOR VEHICLE

Only fill in these columns if you used PUBLIC TRANSPORT

Only fill in this column if you used a TAXI

	A What was the purpose of your journey? See Note A	B What time did you leave? See Note B	C What time did you arrive? See Note C	D Where did you start your journey? (Tick Home or give the name of the village, town or area) See Note D	E Where did you go to? (Tick Home or give the name of the village, town or area) See Note E		F What method of travel did you use for each stage of your journey? See Note F	G How far did you travel? (Miles) See Note G	H How long did you spend travelling? (Minutes) See Note H	I How many people travelled including you? See Note I	J Which car or other motor vehicle did you use? See Note J	K Were you the driver (D) or a passenger (P)? See Note K	L How much did you pay for parking? See Note L	M How much did you pay for road tolls/ congestion charges? See Note M	N What type of ticket did you use? See Note N	O How much did your ticket cost? See Note O	P How many times did you board? See Note P	Q How much did your share of the taxi cost? See Note Q
1	Go to work	Time: 8:15 ☑ am ☐ pm	Time: 9:00 ☑ am ☐ pm	☑ Home	☐ Home Pendleton, Salford	1	Car	18	45	1	Fiesta	☑ D ☐ P	£2 :00 ☐ Nil	£ : ☑ Nil		£ : ☐ Nil		£ : ☐ Nil
						2						☐ D ☐ P	£ : ☐ Nil	£ : ☐ Nil		£ : ☐ Nil		£ : ☐ Nil
						3						☐ D ☐ P	£ : ☐ Nil	£ : ☐ Nil		£ : ☐ Nil		£ : ☐ Nil
2	Go Home	Time: 5:30 ☐ am ☑ pm	Time: 6:20 ☐ am ☑ pm	☐ Home Pendleton, Salford	☑ Home	1	Car	18	50	1	Fiesta	☑ D ☐ P	£ : ☑ Nil	£ : ☑ Nil		£ : ☐ Nil		£ : ☐ Nil
						2						☐ D ☐ P	£ : ☐ Nil	£ : ☐ Nil		£ : ☐ Nil		£ : ☐ Nil
						3						☐ D ☐ P	£ : ☐ Nil	£ : ☐ Nil		£ : ☐ Nil		£ : ☐ Nil
3	Go out for meal with friends	Time: 7:00 ☐ am ☑ pm	Time: 8:05 ☐ am ☑ pm	☑ Home	☐ Home Liverpool City Centre	1	Walk	1	20	2		☐ D ☐ P	£ : ☐ Nil	£ : ☐ Nil		£ : ☐ Nil		£ : ☐ Nil
						2	Train	8	30	2		☐ D ☐ P	£ : ☐ Nil	£ : ☐ Nil	Single	£2 :90 ☐ Nil	1	£ : ☐ Nil
						3	Bus	15	8	2		☐ D ☐ P	£ : ☐ Nil	£ : ☐ Nil	Single	£1 :00 ☐ Nil	1	£ : ☐ Nil
4	Go Home	Time: 10:30 ☐ am ☑ pm	Time: 10:55 ☐ am ☑ pm	☐ Home Liverpool City Centre	☑ Home	1	Taxi	10	25	2		☐ D ☐ P	£ : ☐ Nil	£ : ☐ Nil		£ : ☐ Nil		£ 8 :00 ☐ Nil
						2						☐ D ☐ P	£ : ☐ Nil	£ : ☐ Nil		£ : ☐ Nil		£ : ☐ Nil
						3						☐ D ☐ P	£ : ☐ Nil	£ : ☐ Nil		£ : ☐ Nil		£ : ☐ Nil
5		Time: ☐ am ☐ pm	Time: ☐ am ☐ pm	☐ Home	☐ Home	1						☐ D ☐ P	£ : ☐ Nil	£ : ☐ Nil		£ : ☐ Nil		£ : ☐ Nil
						2						☐ D ☐ P	£ : ☐ Nil	£ : ☐ Nil		£ : ☐ Nil		£ : ☐ Nil
						3						☐ D ☐ P	£ : ☐ Nil	£ : ☐ Nil		£ : ☐ Nil		£ : ☐ Nil
6		Time: ☐ am ☐ pm	Time: ☐ am ☐ pm	☐ Home	☐ Home	1						☐ D ☐ P	£ : ☐ Nil	£ : ☐ Nil		£ : ☐ Nil		£ : ☐ Nil
						2						☐ D ☐ P	£ : ☐ Nil	£ : ☐ Nil		£ : ☐ Nil		£ : ☐ Nil
						3						☐ D ☐ P	£ : ☐ Nil	£ : ☐ Nil		£ : ☐ Nil		£ : ☐ Nil

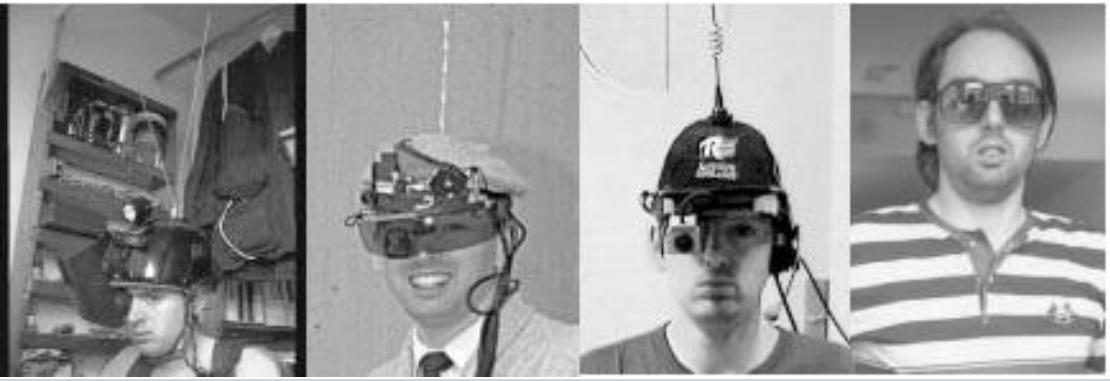
USE THIS SPACE FOR ANYTHING ELSE YOU WANT TO TELL US

EXTRA JOURNEYS
If you made more than 6 journeys on this day please use the extra space towards the back of the booklet

The gold standard is direct observation

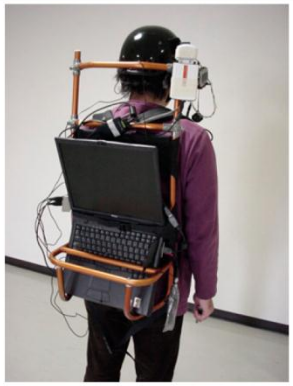
Visual Lifelogging Devices

- Much past research focus on miniaturising hardware and increasing battery-life + storage e.g. visual lifelogging domain

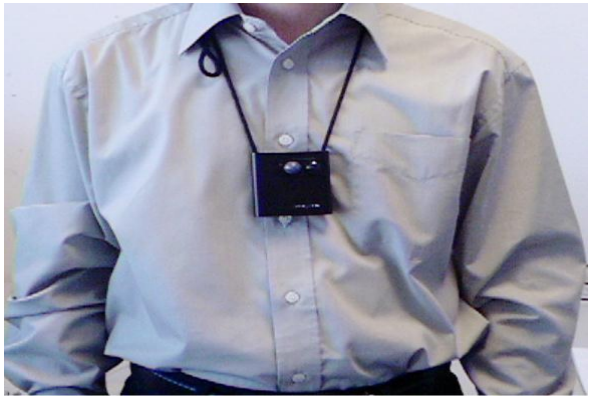


Steve Mann. Wearable computing: a first step toward personal imaging. Computer, 30:25–32, Feb 1997.

TIMELINE



Tano *et. al.* University of Electro-Communications, Tokyo, Japan



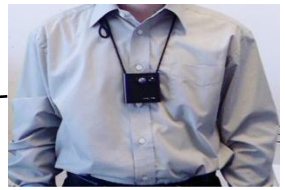
Microsoft Research SenseCam


STOP

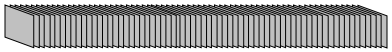

EAT.
EAT.
EAT.


Safety Information

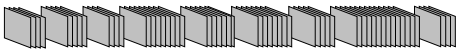
Daily Browser Overview



SenseCam Images of a day (about 3,000)



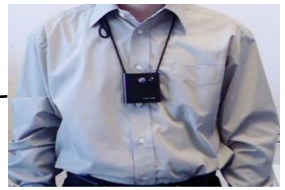
Event Segmentation

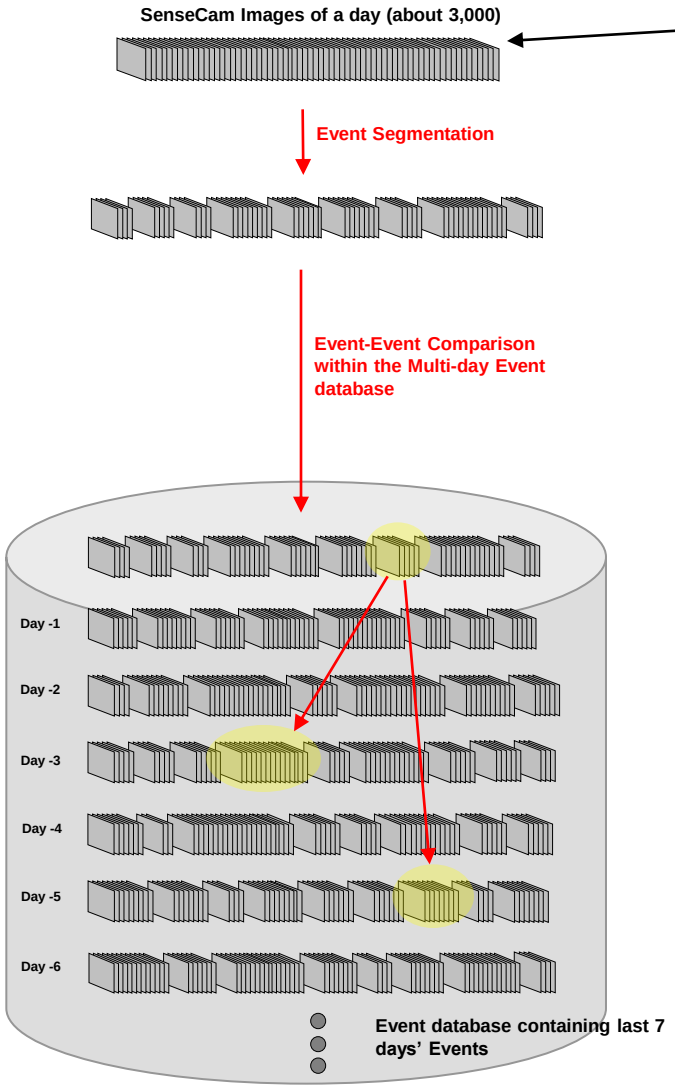


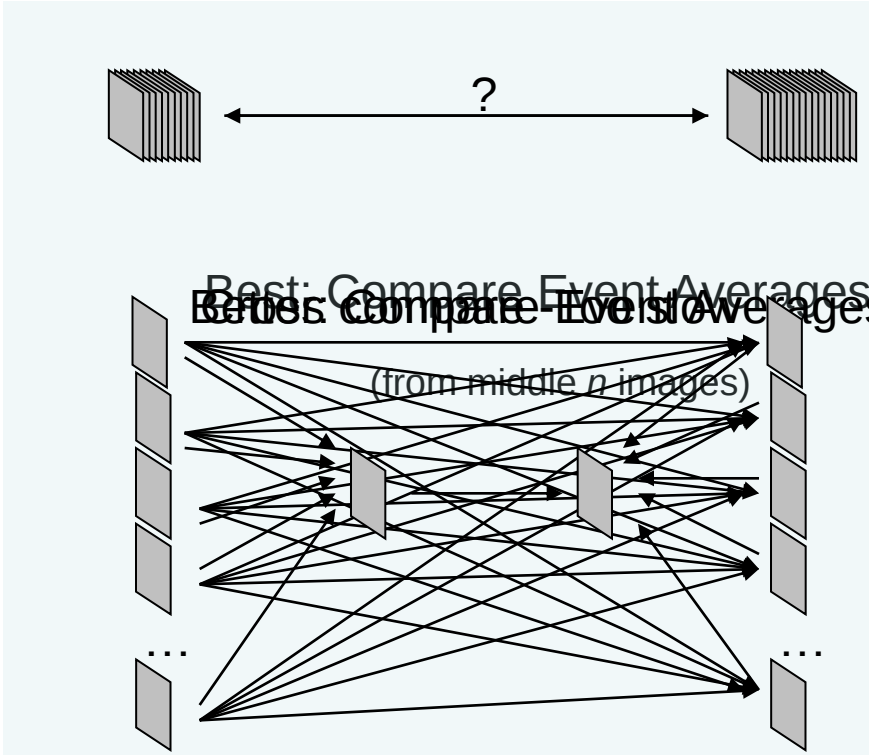
EVENT SEGMENTATION

Using MOTION sensors – very quick & accurate

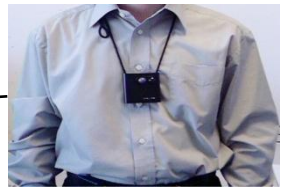
Visual Search Facilities







Selecting Event “Keyframe”



SenseCam Images of a day (about 3,000)

Event Segmentation

Event-Event Comparison within the Multi-day Event database

Day -1

Day -2

Day -3

Day -4

Day -5

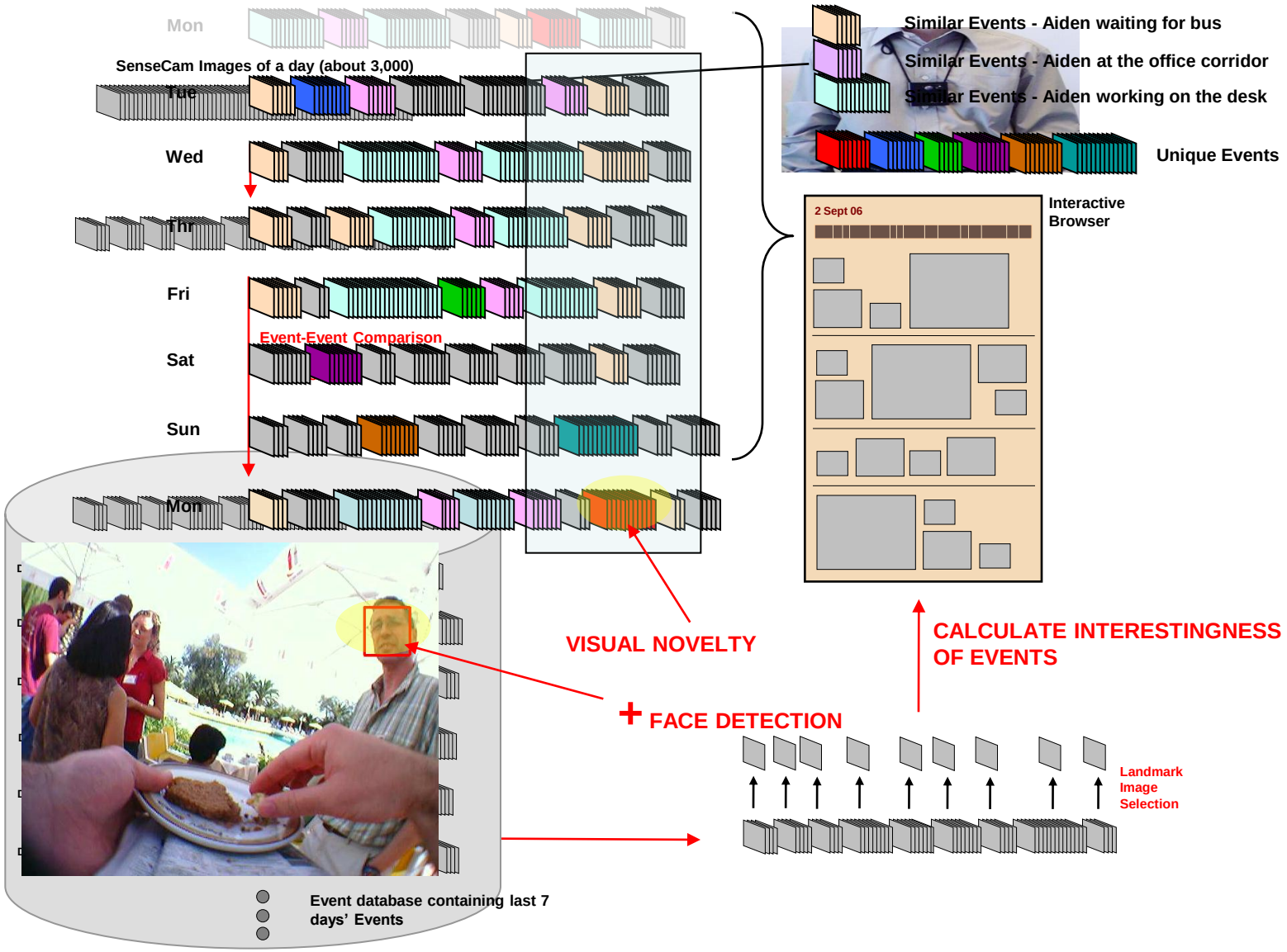
Day -6

Event database containing last 7 days’ Events

Landmark Image Selection

Best QUALITY image around MIDDLE of event

Suggest Interesting Events



My Visual Diary with SenseCam

hlee: 76,430 photos (25 days)

MY ACCOUNT | SIGN OUT | ABOUT

CALENDAR

MAY 2006

S	M	T	W	T	F	S
30	1	2	3	4	5	6
7	8	9	10	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30	31	1	2	3
4	5	6	7	8	9	10

DURATION ▶

CAPTION SEARCH

WEEKLY SUMMARY

Selected day is shown below in the context of whole week. Move mouse curosr over to see other similar Events in the week

S M T W T F S

29 May 2006

19 EVENTS

Drag the slider bar to adjust the number of Important Events

0 am 6 am 12pm 6pm 0am

I was chatting with Gareth on the conference in July. Quite a few chats today !

ADD TO FAVE | FIND SIMILAR

My Favourite Events

25 Favourite Events are shown below. Click on the photo to replay all photos within the Event.

| 1 | 2 | 3 |

Sort by: TIME | SIMILARITY | #PEOPLE

16:20 (Duration: 08m 43s)
14 APR 2006 ▶

13:45 (Duration: 14m 05s)
14 APR 2006 ▶

10:02 (Duration: 23m 56s)
13 APR 2006 ▶

14:39 (Duration: 15m 30s)
12 APR 2006 ▶

11:25 (Duration: 06m 21s)
12 APR 2006 ▶

09:52 (Duration: 01m 03s)
12 APR 2006 ▶

So what can the SenseCam be used for?

Case study:
- Quantifying active travel self report error

UK National Travel Survey

Area Add H CL P

In confidence

Travel Survey

Travel record of

Travel week: Start day | Finish day

Start date | Finish date

Please use black or blue ink if possible

Thank you very much for your help

Your interviewer

Please see the notes on the reverse of this flap

A few points to remember when filling in the travel record:

1. We are interested in all types of transport; walks and bike journeys as well as cars and public transport.

2. Use a new line for each journey (e.g. go to work, go home). From column F use a new line for each method of travel you used for each stage of your journey (e.g. car, train, bus, walk).
3. On days 1-6 only include walks of a mile or more (it takes approximately 20 minutes to walk a mile). On day 7 include all walks.
4. Drivers: On days 1 and 7 please remember to enter your gauge readings on the Fuel and Mileage Chart.
5. If you make more than 6 journeys there is space at the end of the record to write down extra journeys.

1. Quantifying error on self-report

Widely used, important for trends, used with other devices

Errors potentially come from recall, perception, human factors and social desirability

We intend to investigate the size of any error on self-reported journey behaviour

Error = a + b + c + d +?

a – systematic error
b – intra-person variability
c – inter-person variability
d – modal effects
? – regular vs. irregular

Research questions

1. Will people wear it?

2. How does SenseCam and Self-report compare?

3. What are the sources of any error?

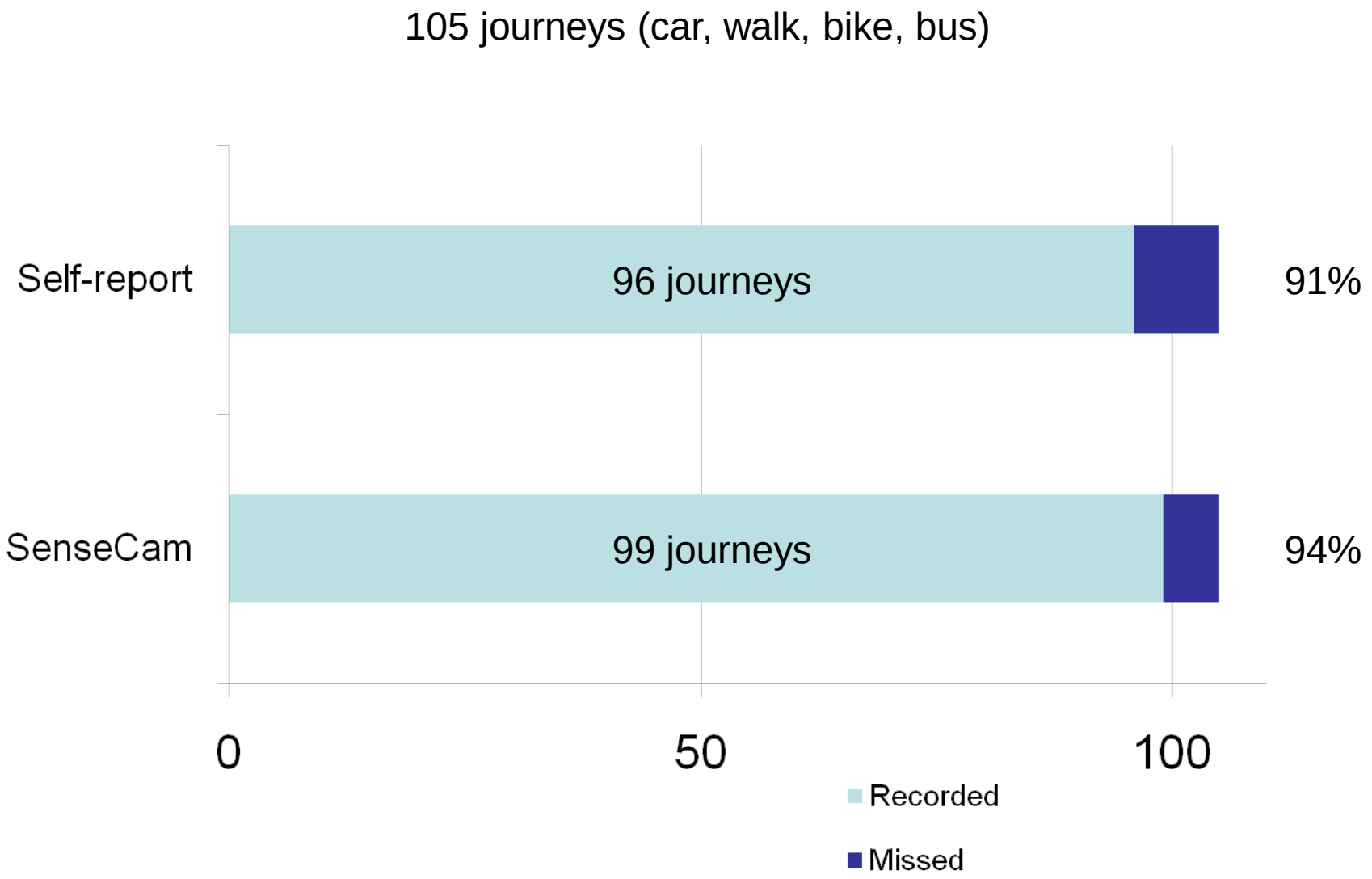
Study

Protocol: Wear SenseCam and complete travel diary for one day

Participants: 20 volunteers

Structured interviews about burden and experience

Will people wear SenseCam?


105 journeys (car, walk, bike, bus)
Self-report
96 journeys
91%
SenseCam
99 journeys
94%
0
50
100
Recorded
Missed

How do self report and SenseCam data compare?

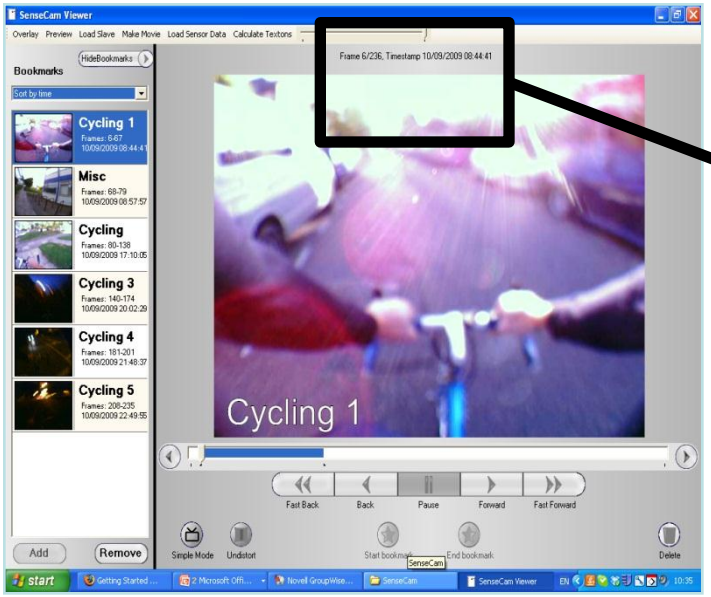
DAY:	DATE:	STAGES These columns are for entering the details of each stage of your journey							
Journeys Please record each journey using a separate row and remember to tell us about short journeys									Only fill this column if you used a CAR or OTHER MOTOR VEHICLE
A What was the purpose of the journey?	B What time did you leave?	C What time did you arrive?	D Where did you start your journey? (Tick home or give the name of the village , town or area?	E Where did you go to? (Tick home or give the name of the village, town or area		F What method of travel did you use for each stage of your journey?	G How far did you travel? (Miles)	H How long did you spend travelling? (Minutes)	I How many people travelled including you?	J Were you the driver (D) or passenger (P)
1. To Work	Time: 8.40 ☑ am ☐ pm	Time: 9.00 ☑ am ☐ pm	☑ Home Abingdon rd, Ox	☐ Home Old Road Campus, Heading'ton, Ox	1	Bike	3.5	20	-	☑ D ☐ P
					2					☐ D ☐ P
					3					☐ D ☐ P
2. Shop from Work	Time: ~~8.50~~ 5.00 ☐ am ☑ pm	Time: 5.20 ☐ am ☑ pm	☐ Home Old Rd	☑ Home Abingdon Rd	1	Bike	3.5	20		☐ D ☐ P
					2					☐ D ☐ P
					3					☐ D ☐ P
3. To Shop	Time: 7.50 ☐ am ☑ pm	Time: 8.00 ☐ am ☑ pm	☑ Home Abingdon rd,	☐ Home Town Centre	1	Bike	1	10		☐ D ☐ P
					2					☐ D ☐ P
					3					☐ D ☐ P
4. To Home	Time: 8.10 ☐ am ☑ pm	Time: 8.20 ☐ am ☑ pm	☐ Home Town	☐ Home Abingdon Rd.	1	Bike	1	10		☐ D ☐ P
					2					☐ D ☐ P
					3					☐ D ☐ P
5. To Pub	Time: 9.35 ☐ am ☑ pm	Time: 9.50 ☐ am ☑ pm	☑ Home Abingdon Rd,	☐ Home Little Clarendon St.	1	Bike	2	15		☐ D ☐ P
					2					☐ D ☐ P
					3					☐ D ☐ P
6. To Home	Time: 10.45 ☐ am ☑ pm	Time: 11.00 ☐ am ☑ pm	☐ Home Little Clarendon St.	☑ Home Abingdon Rd	1	Bike	2	15		☐ D ☐ P
					2					☐ D ☐ P
					3					☐ D ☐ P

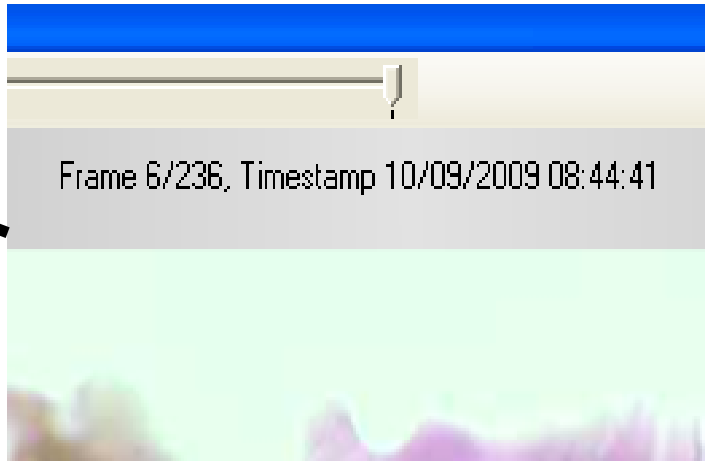
USE THIS SPACE FOR ANYTHING ELSE YOU WANT TO TELL US

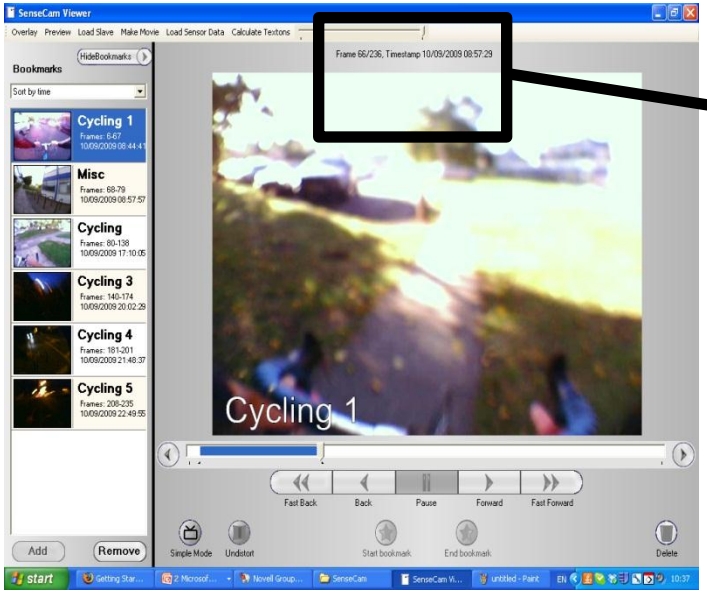
3					☐ D ☐ P
1	Bike	~~3~~ 15	20		☐ D ☐ P
2					☐ D ☐ P
3					☐ D ☐ P
1	Bike	1	10		☐ D ☐ P

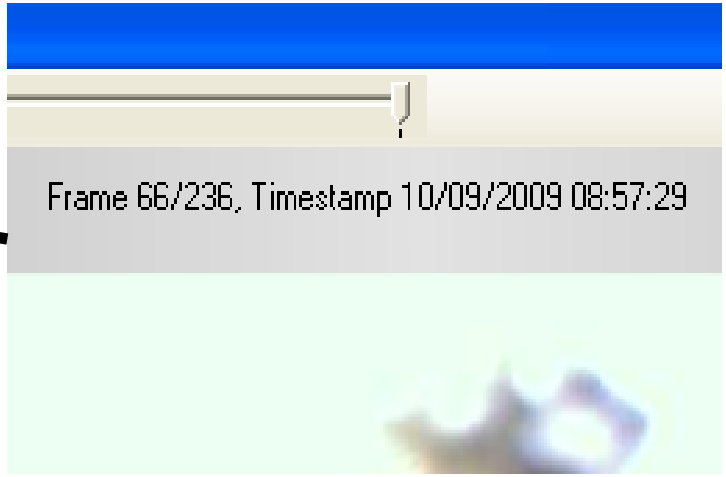
Journey time = 20 minutes

How did they compare?



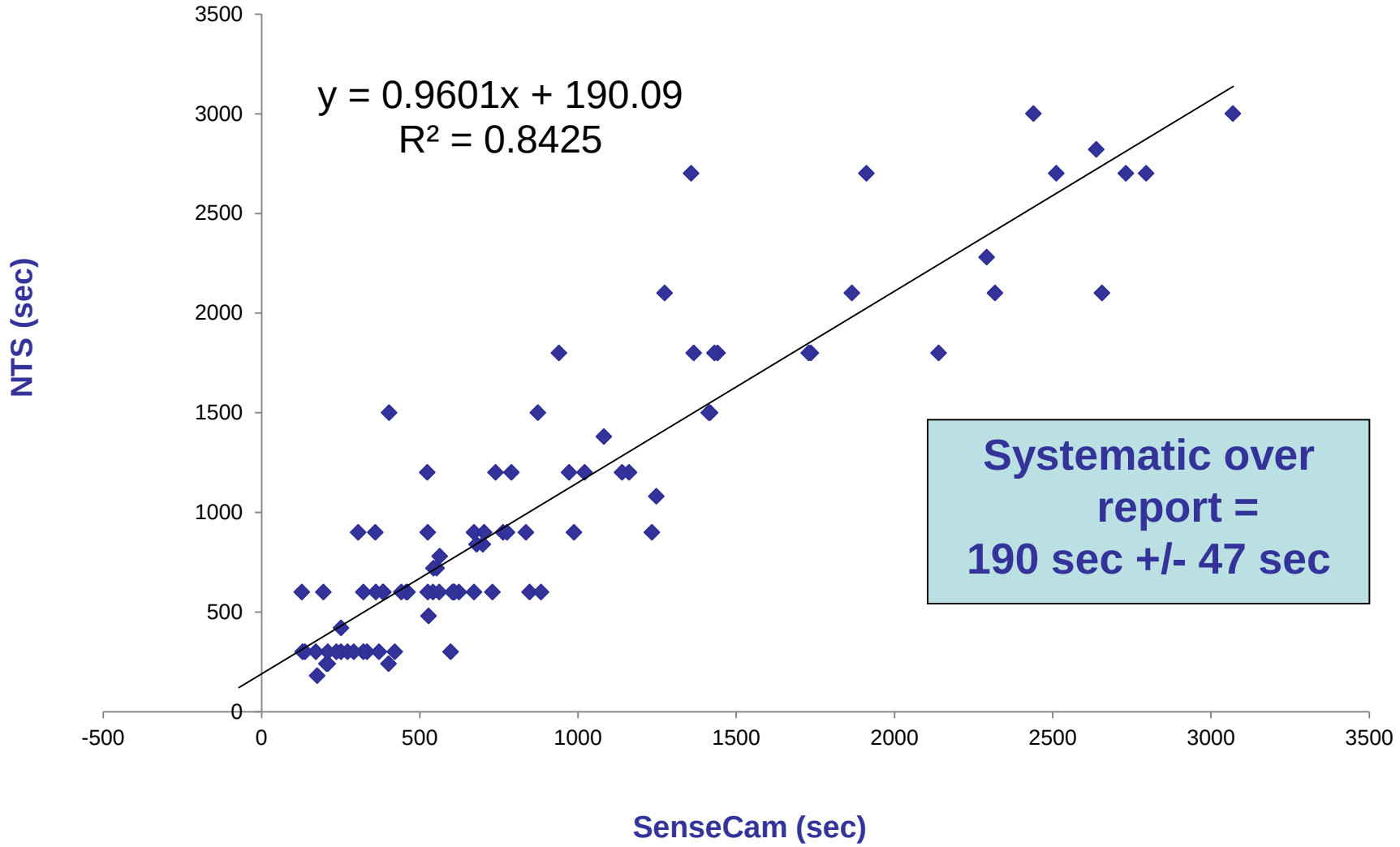


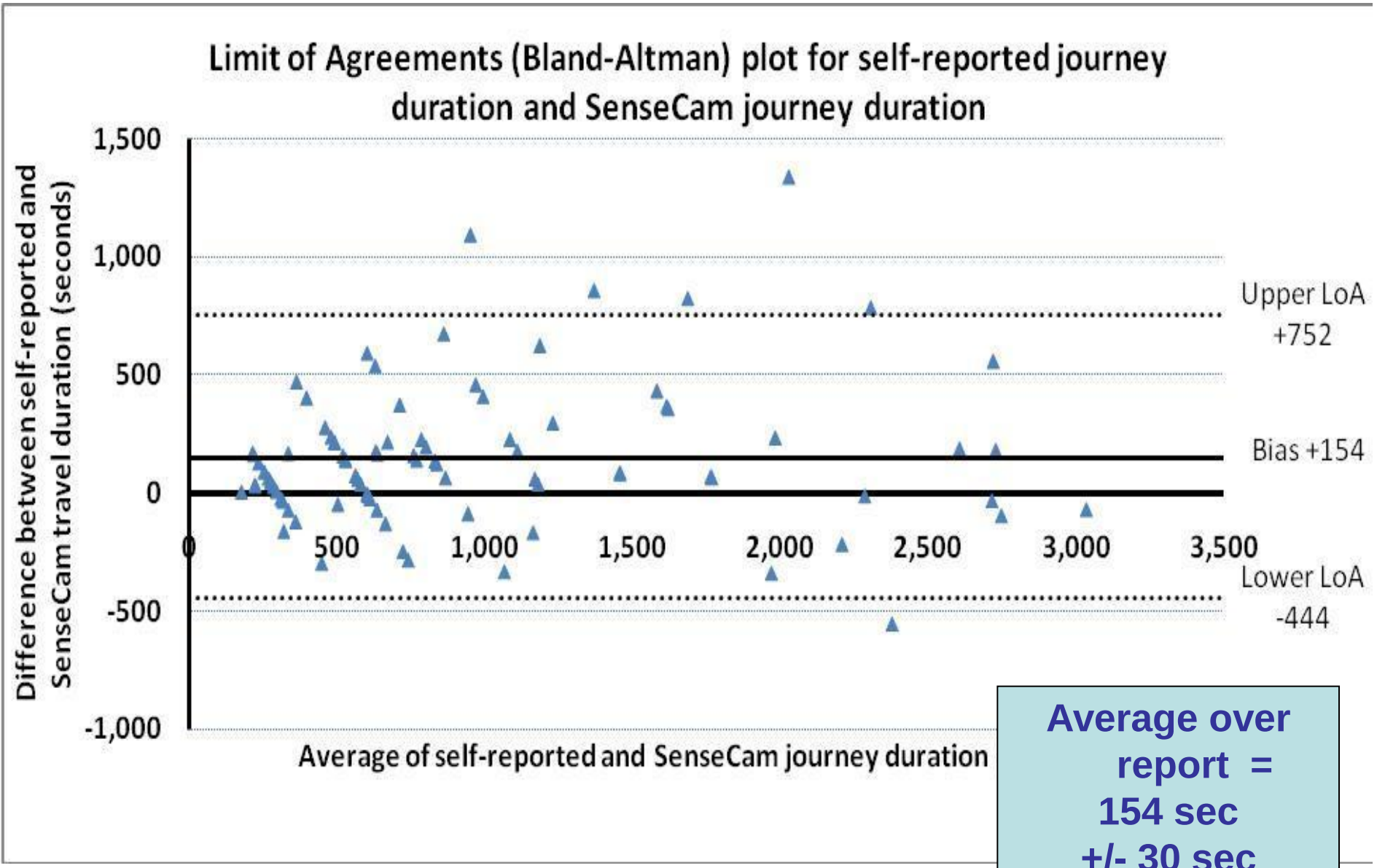




Journey time = 12 min 48 sec

Correlation





Average over report = 154 sec +/- 30 sec

Car +2 min 08 sec (S.E. 60 sec)

Walk +1 min 41 sec (S.E. 45 sec)

Bike +4 min 33 sec (S.E. 64 sec)

All journeys
+2 min 30 sec
(S.E. 32 sec)

So what…?

154 sec per journey = 6 min 42 sec per day*

= 54 min per week

= 36% of recommended amount**

***3 'Active transportation' journeys per participant per day**

****Physical activity recommendations; 30 min per day, 5 days per week…or 150 minutes per week**

(Chief Medical Officer, Department of Health)

Why are people over-reporting travel time?

Retrospective interviews:

Example A;

“I said 25 minutes because it took 10 minutes to get the kids in the car”

Example B;

“I think about the time I leave the house and the time I walk into the office, not the time spent cycling”

OK it's promising to investigate inherent error in active travel self-report … what else can it be useful for with respect to physical activity?

2. Combination with GPS

Location important for many reasons

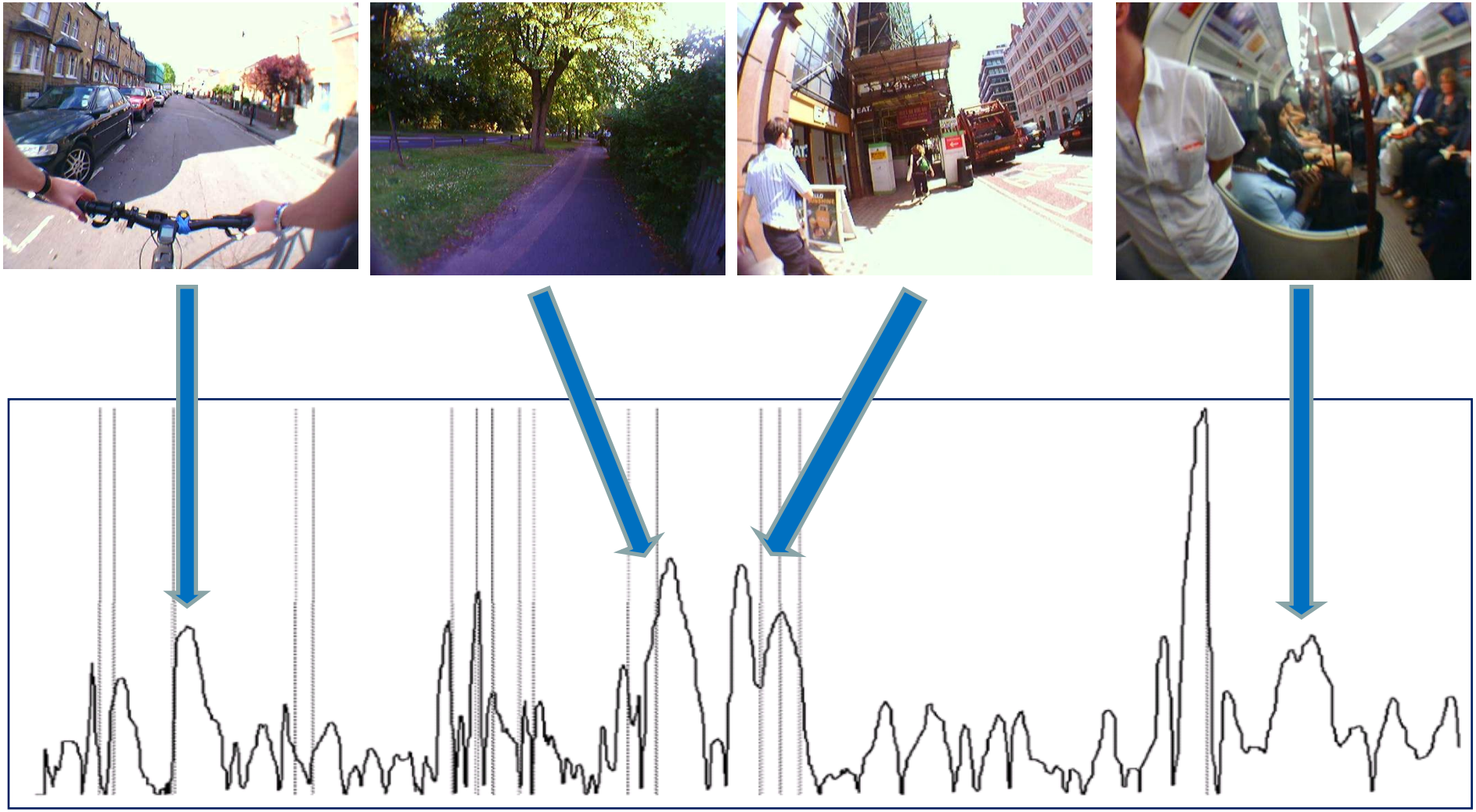
Limitations include cold start, signal loss and estimation of mode from speed or self-report

(QStarz BT Q1000X)

3. Combination with accelerometer

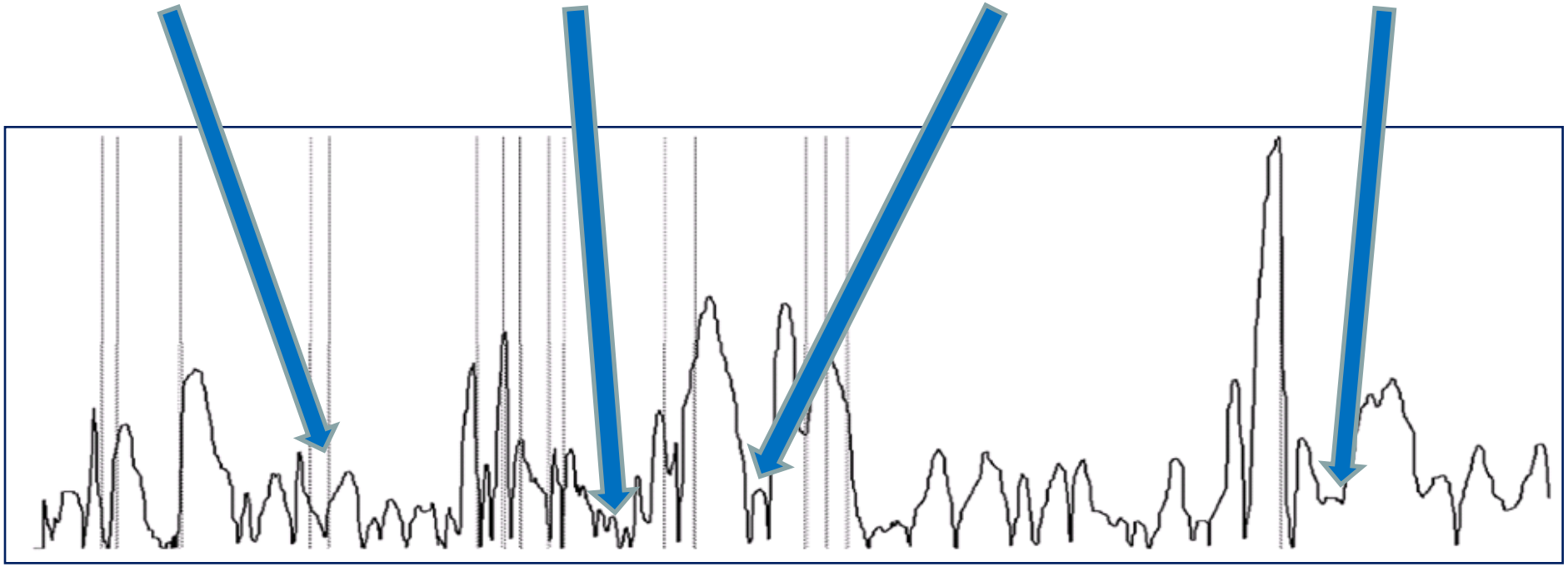
Intensity important

Challenge to verify mode or behaviour from trace

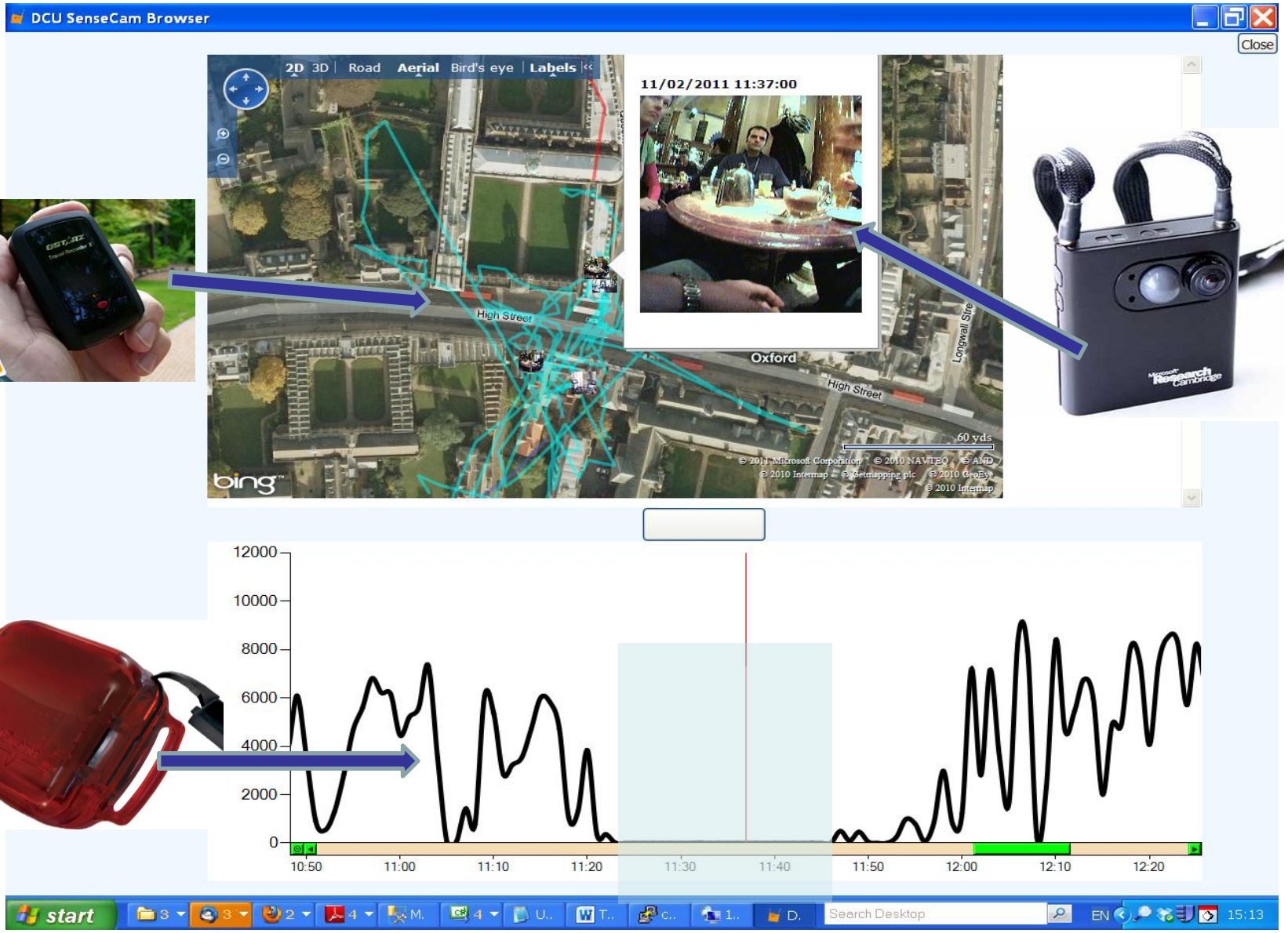






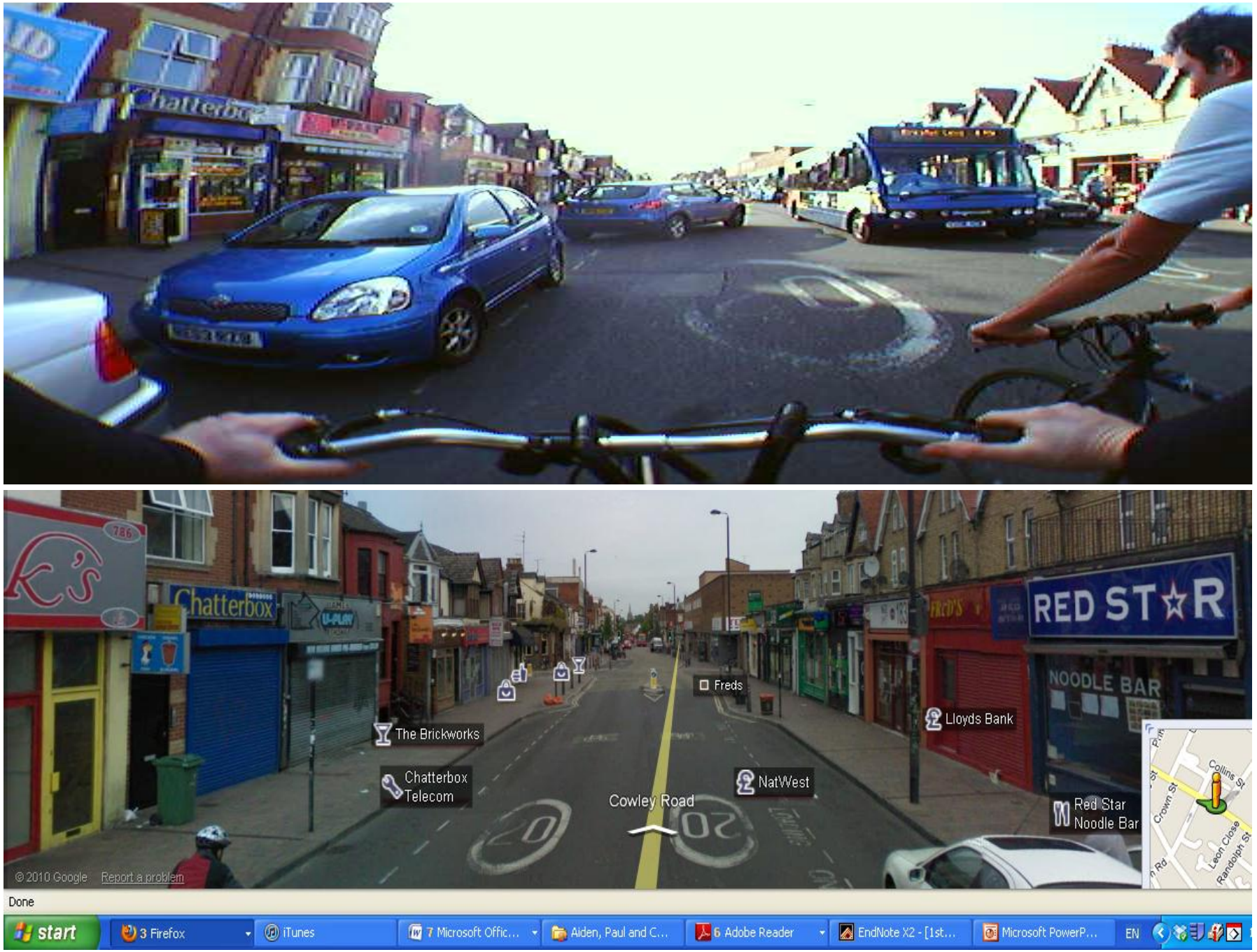


MIS-CLASSIFYING SEDENTARY BEHAVIOUR AS NON-WEAR TIME…



5. Environmental audit or determinants

Cycle lane use


Chatterbox
K's
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Chatterbox
U-PLAY
RED ST☆R
NOODLE BAR
Freds
Lloyds Bank
The Brickworks
Chatterbox Telecom
NatWest
Cowley Road
Red Star Noodle Bar
© 2010 Google
Report a problem
Done
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iTunes
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Aiden, Paul and C...
6 Adobe Reader
EndNote X2 - [1st...
Microsoft PowerP...
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Automated activity detection

SENSECAM VIEWER

Driving
150m 27s

Close

Wednesday
09 September 2009

Show Calendar

Touch the button above to view different days

1	Driving	76m 34s
2	Driving	73m 53s

Add Photos

Help

2903 Photos (07:07 AM - 22:09 PM)

You can touch one of the events below to view the photos within it.

SENSECAM VIEWER

Driving
150m 27s

Close

Wednesday
09 September 2009

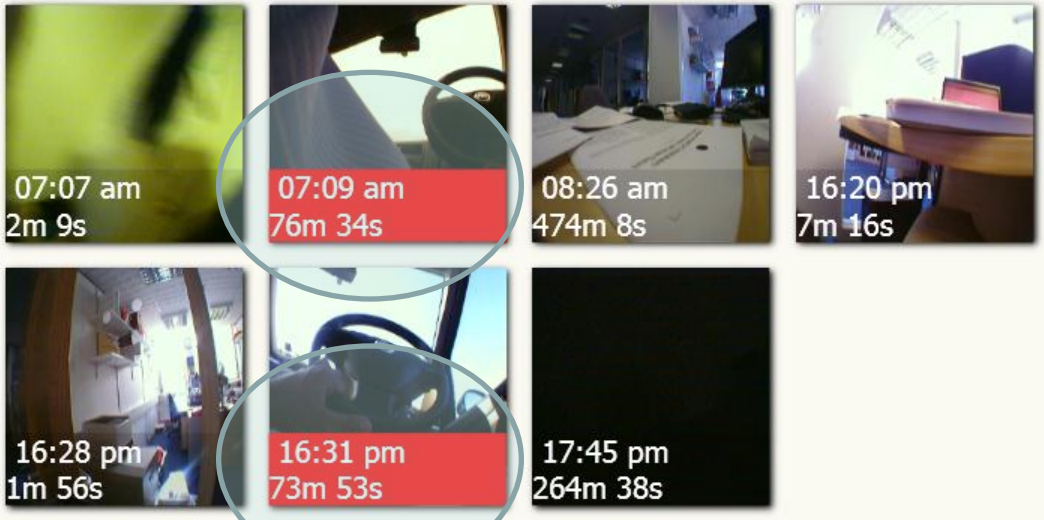
2903 Photos (07:07 AM - 22:09 PM)

You can touch one of the events below to view the photos within it.

Show Calendar

Touch the button above to view different days

1 Driving 76m 34s
2 Driving 73m 53s



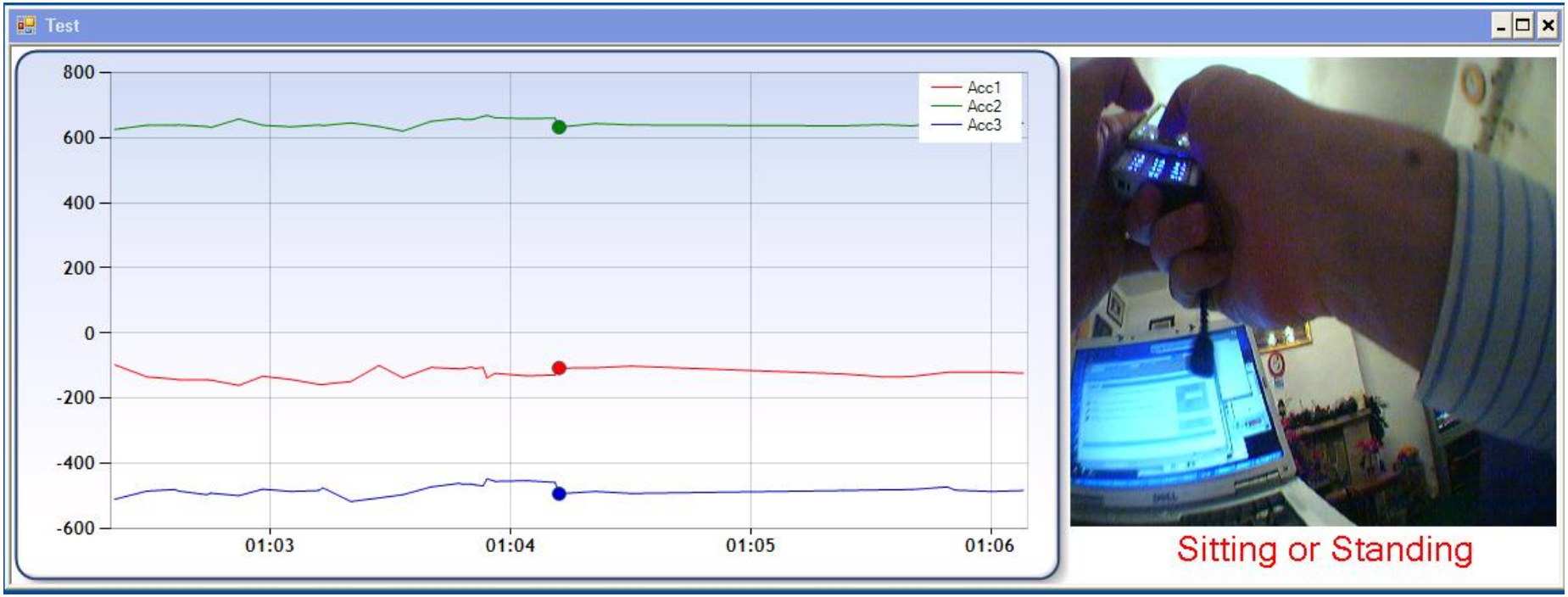
Add Photos

Help

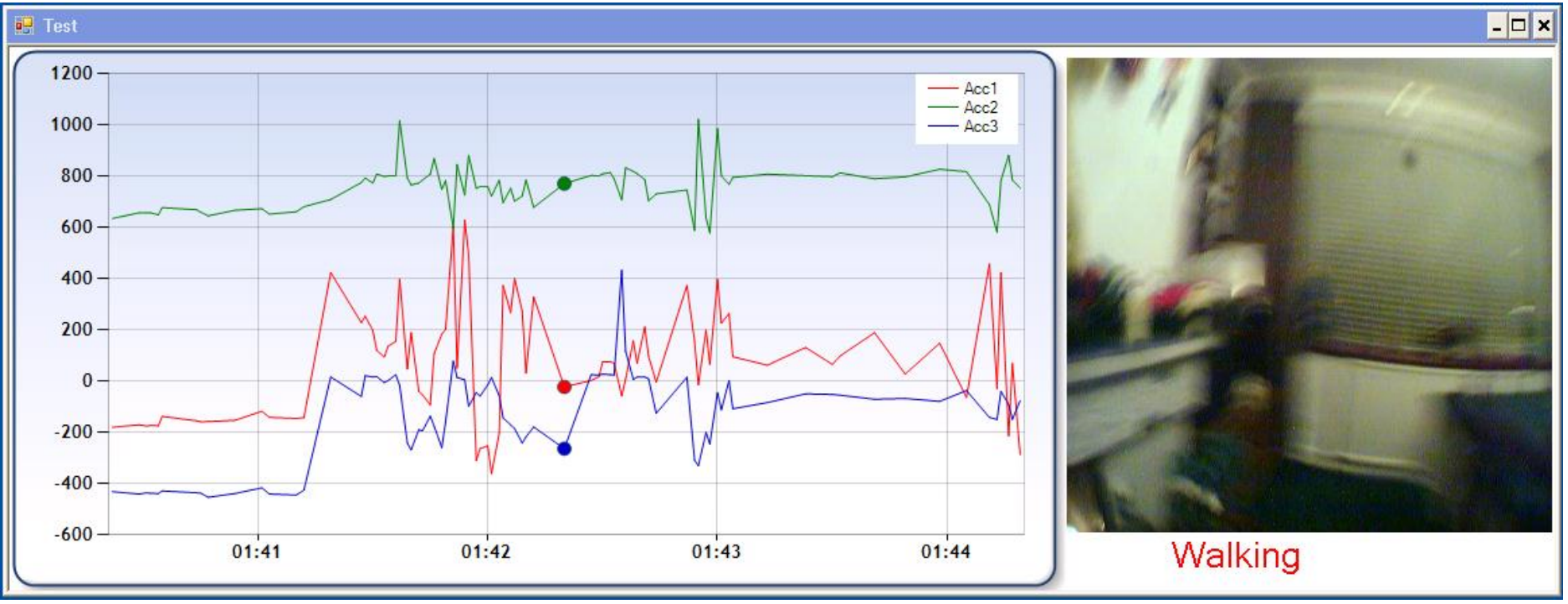
Identifying Activities

Sitting/Standing = 75% accurate

Using a range of classifiers: Logistic Regression, Naïve Bayes, J48, SVM, Etc.



Identifying Activities
Walking = 77% Accurate

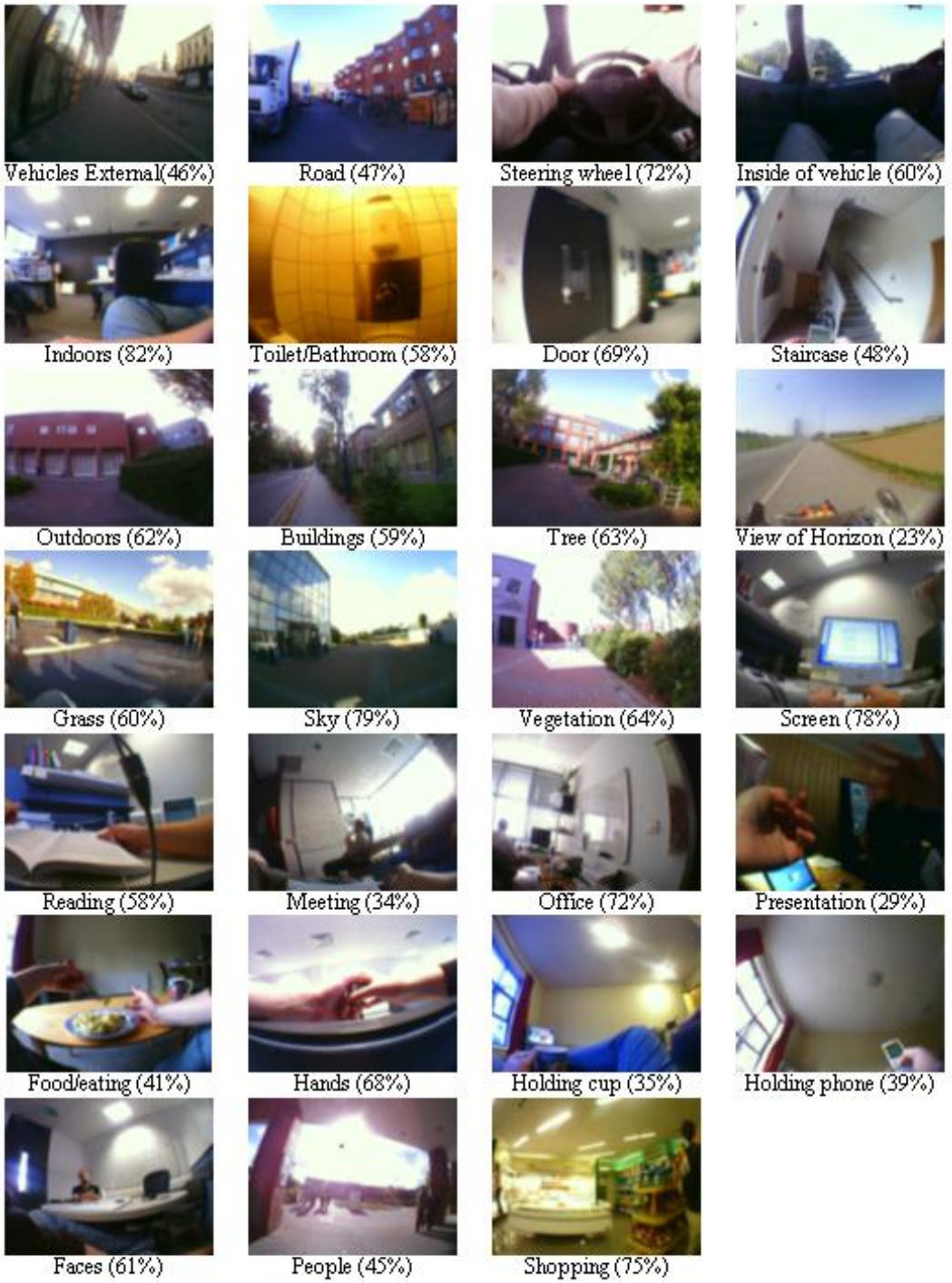


Identifying Activities
Driving = 88% Accurate

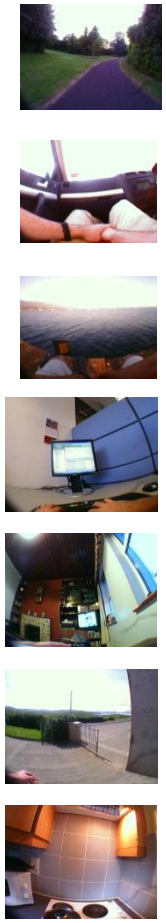
Activity Recognition *using Images*

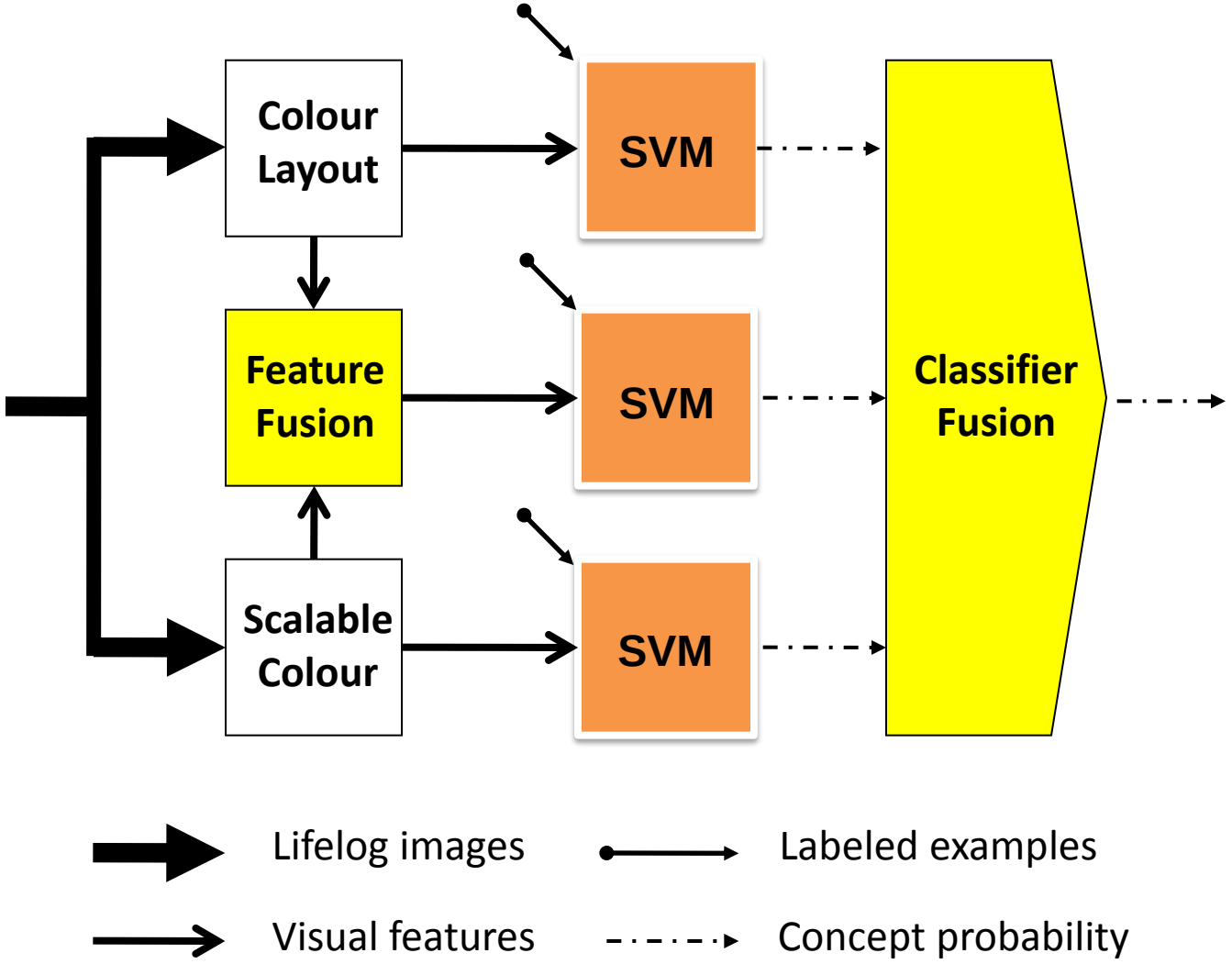
- 27 “activities”

- Validated on 95k annotated images

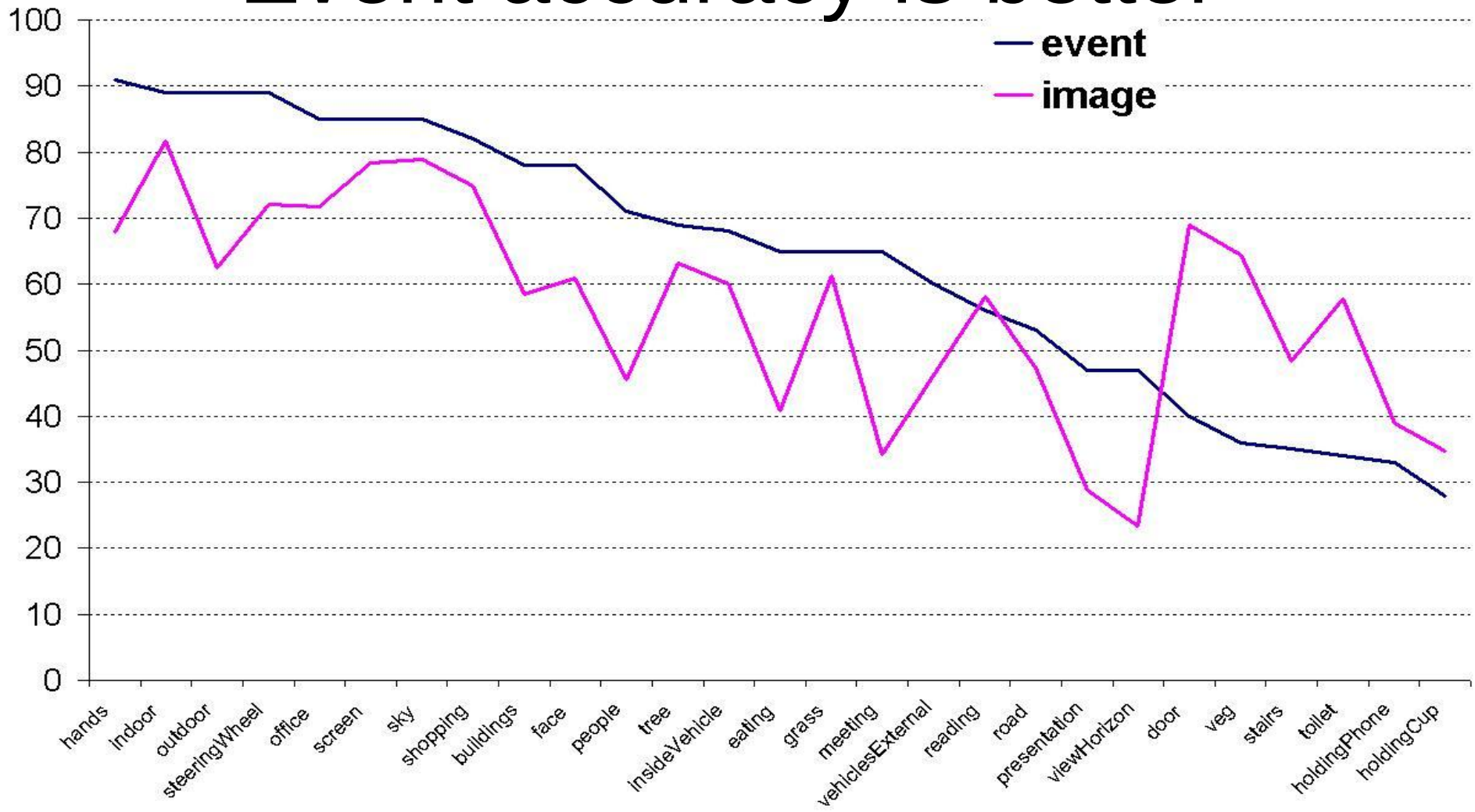


Concept detection process

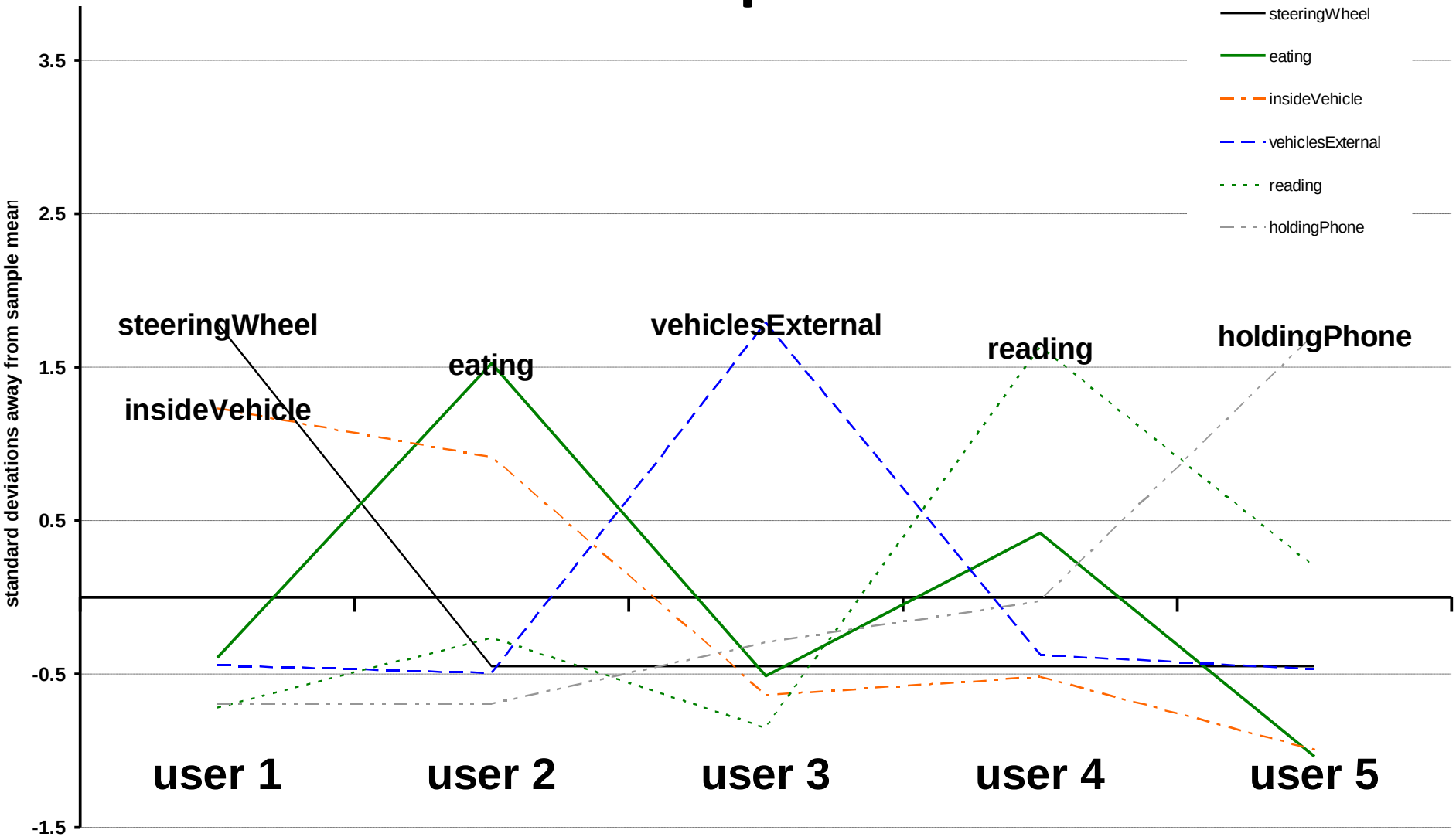




Event accuracy is better



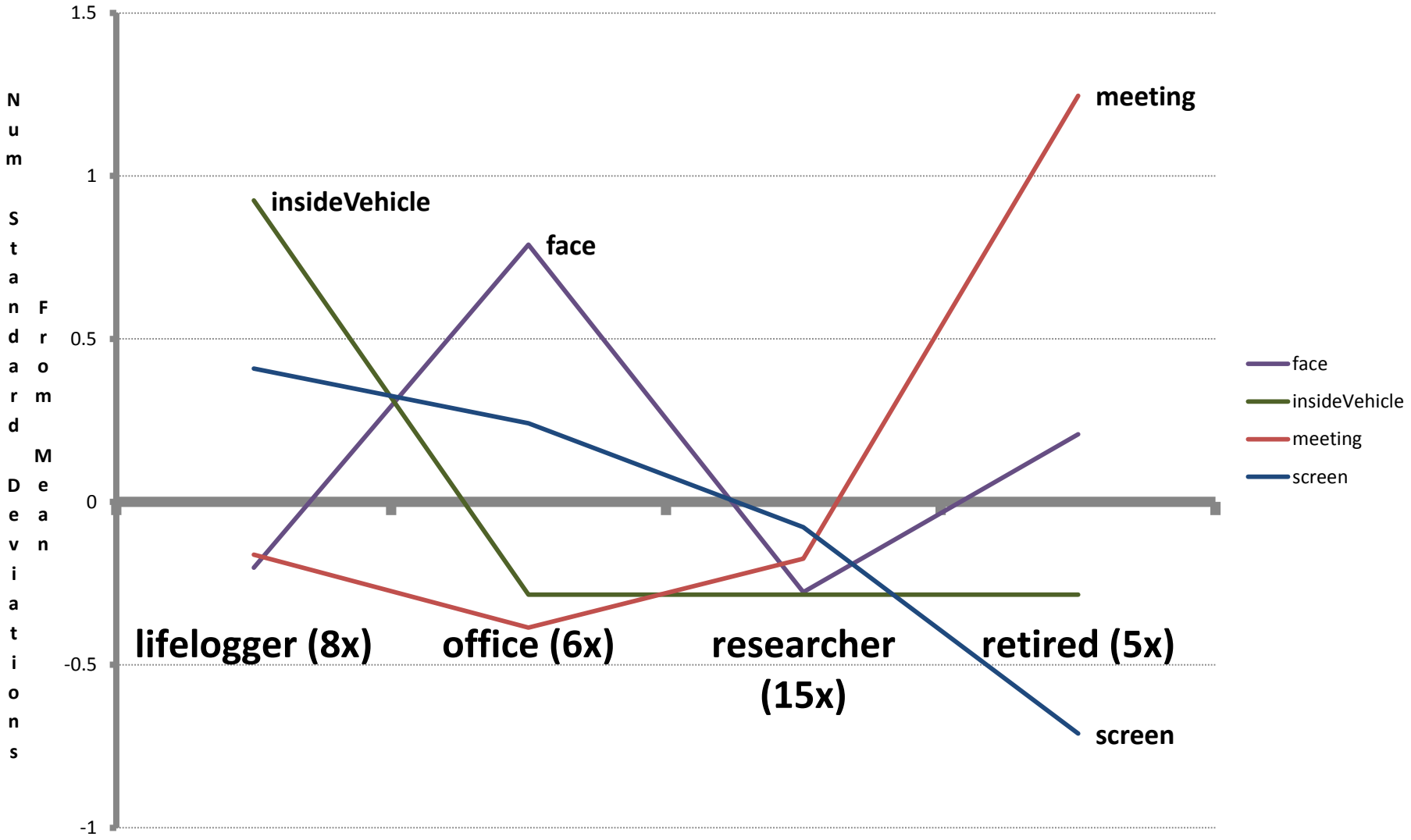
Comparison of Lifestyle Within Social Groups



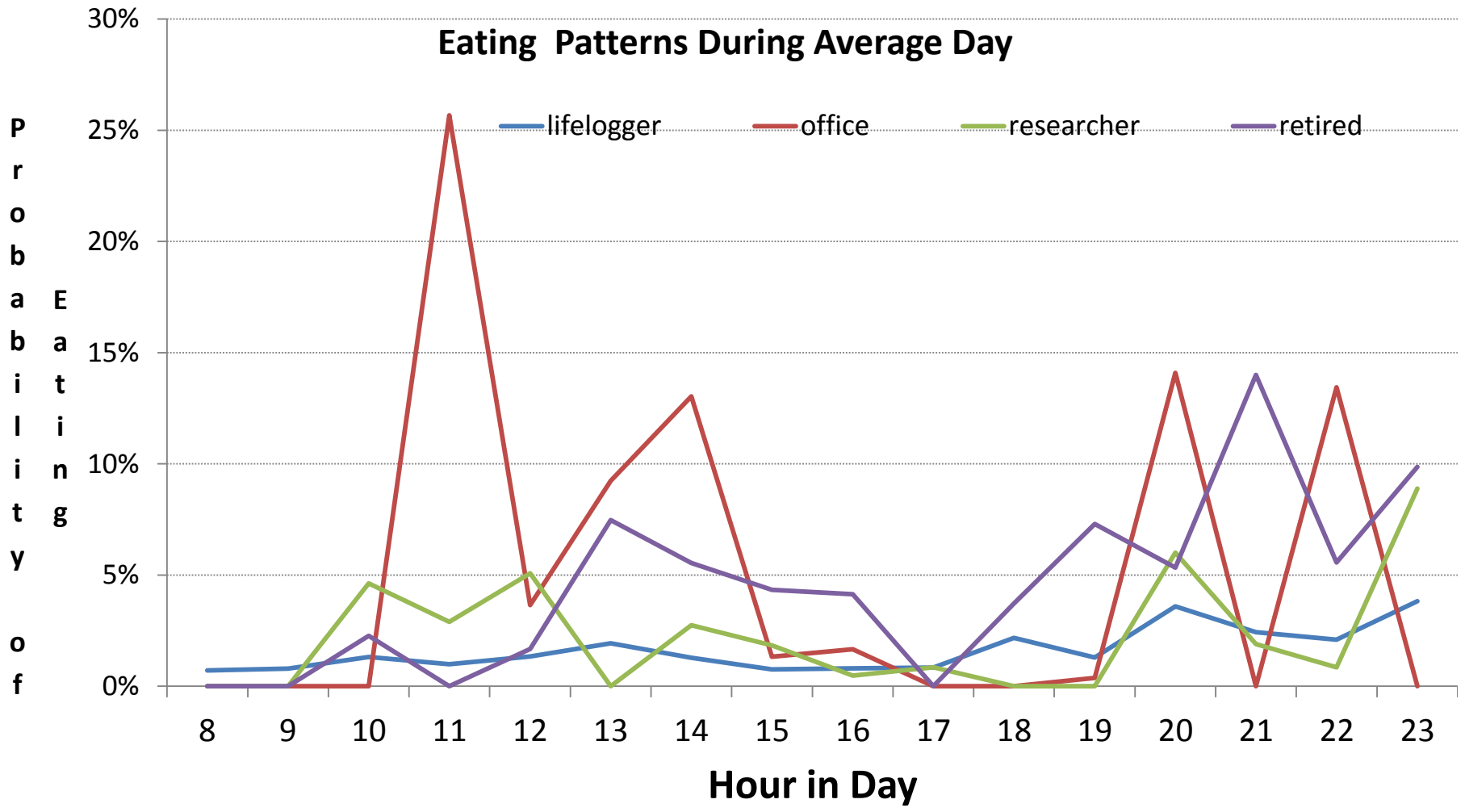
But let's use more people (34x)...

Participant Group and (#)	Median # of Days of SenceCam data	Median # of Events per Day	Median # SenseCam Images per Day	Median SenseCam wear per Day
Office Workers (6)	7	19.5	1,599	6h 55m
Researchers (15)	8	20	1,640	7h 15m
Retired (5)	**3**	**23**	**1,886**	**7h 45m**
Regular lifeloggers (8)	42	18.5	1,517	10h 21m
Overall Averages	15.1	20.9	1,712	8h 45m

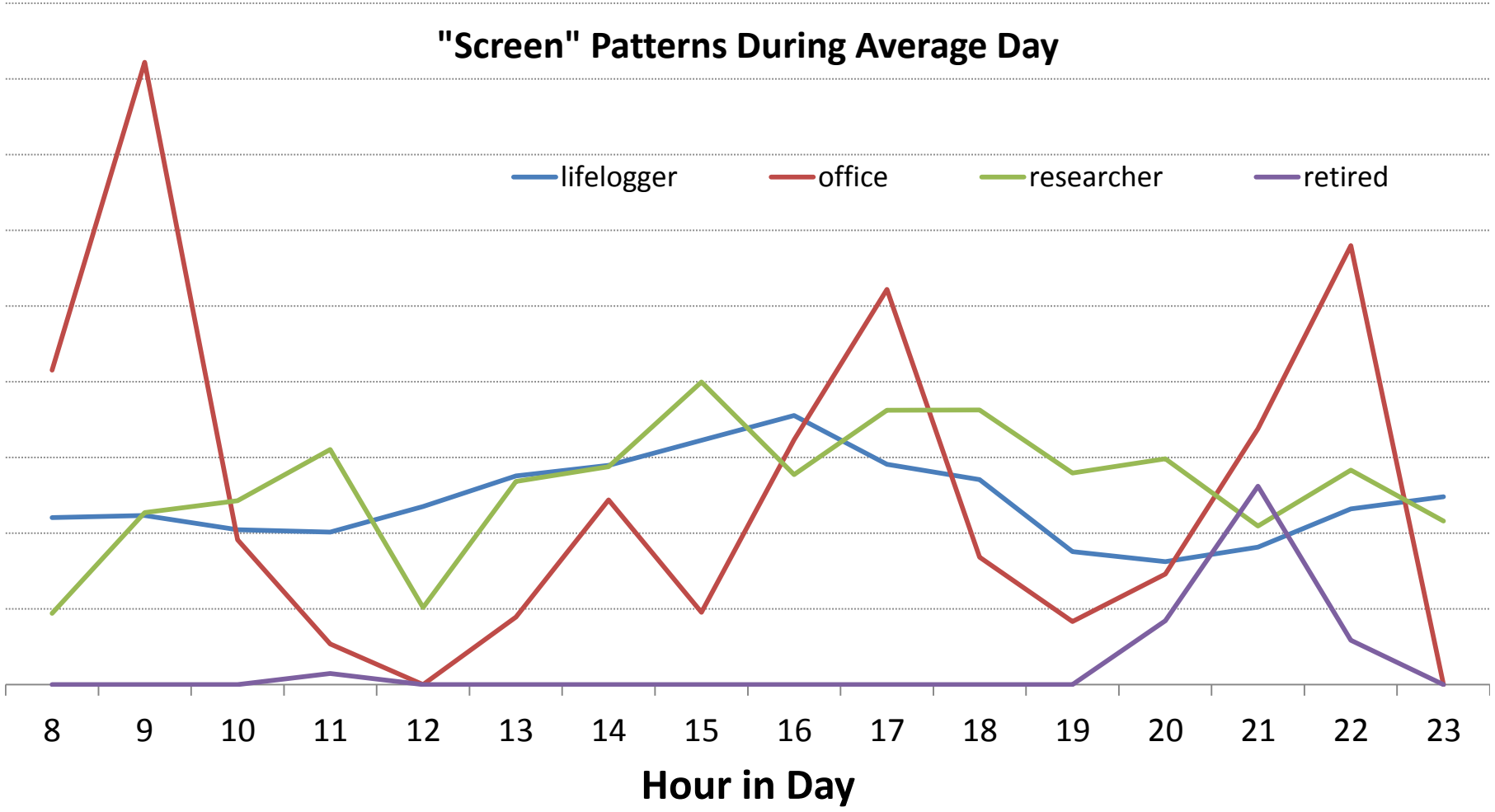
Differences between groups...



When do people eat?



When do people look at screens?



In Conclusion:

Computer Scientists:
Measuring health-related behaviour offers many opportunities

Physical Activity Researchers:
SenseCam offers potential as a powerful context reinstatement tool

3rd March 2011 – EPARC & CWPHS, San Diego

Using wearable image sensing to measure physical activity & sedentary behavior

Aiden Doherty

Thanks to
Dr Charlie Foster
Paul Kelly
Prof. Alan Smeaton
Dr Steve Hodges
Sensors and Devices Group
Microsoft Research Cambridge