National Collaborating Centre for Environmental Health

Factors that affect RF Exposure from Mobile Phones

AIHA – BC/Yukon Local Section
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National Collaborating Centre for Environmental Health
Centre de collaboration nationale en santé environnementale

BC Centre for Disease Control
An Agency of the Provincial Health Services Authority

Background

- Widespread cell phone use
- Ongoing epidemiologic studies
  - IARC
  - Epidemiologic research show largely negative associations, though, some studies link brain cancer and cell phones
  - Look mainly at duration of exposure, not intensity
- Need for better understanding of exposure
- Technology of cell phones is changing

Project

- Recall study
- Software Modified Phone survey
- Field Study
- Analysis of FCC Maximum SAR compliance data

Recall Study

Introduction

- Epidemiologic studies often use self-report of cell phone use as a surrogate for RF exposure:
  - Frequency of calls
  - Average length of call or total duration of calls
  - Years using cell phone
- Previous validation studies have evaluated correlation between self-report and billing records or SMP data
  - Limited by short period of recall or small sample size
- Our study examines the accuracy of recall of mobile phone use by comparing questionnaire data and billing records

Study Objectives

- Evaluate correlation of:
  - Self-reported cell phone use

    vs.
  - Cell phone billing records

- Practical advantages:
  - US companies record incoming and outgoing calls
  - Centralized billing records maintained by company that issues phones to employees
  - Longer term billing records (3 years) available

Methods

- Volunteers recruited from a professional consulting organization that issued mobile phones to employees
  - Used a company-issued phone for at least 1 year
- Web-based questionnaire
  - Mobile phone use going back three years
  - Respondents reported on:
    - Duration of use
    - Number of calls received or made
    - Frequency of calls on weekdays/weekends
    - Time of day

Methods – Analysis

- Compare average frequencies and durations between self report and billing records
- Calculate agreement between two sources as ratio of billing minutes/self report minutes
- Categorize ratio into groups:
  - Within 75%
  - Within 50-74%
  - Within 25-49%
  - Less than 25%
- Correlation analyses

Results – Study Participation

- 72 participants completed questionnaire
- Of these we obtained billing records for 60 participants
- Primarily male (75%) and over 40 (70%)

Results – Overall Summaries

	Number of calls [SD]			Average duration (min) [SD]		
	Question-naire	Billing records	P	Question-naire[a]		P
Per call	--			2.1[b]	2.8	0.01
Per day	7.4 [5.4]	4.6 [3.1]	0.002	15.7 [9.2] Range 1.0-63.3	12.7 [13.7] Range 1.7-41.7	0.22
Per weekday	N/A	N/C		15.3	20.1	0.005
Per weekend day	N/A	N/C		6.5	10.8	<0.001

Reporting Duration: Agreement by Sex

Group	Within 25%		25-50%		50-75%		Outside 75%	
	N	(%)	N	(%)	N	(%)	N	(%)
Total	20	(33.3)	10	(16.7)	15	(21)	15	(34)
Males	15	(33.3)	10	(21.7)	7	(15.2)	13	(28.3)
Females	5	(33.3)	0	(0)	8	(53.3)	2	(13.3)

*Totals do not add up to 61, because not all participants answered these questions in the questionnaire.

Reporting Duration: Agreement by Age

Age Group	Within 25%	25-50%	50-75%	Outside 75%
	N (%)	N (%)	N (%)	N (%)
<40 yrs	7 (32)	0 (0)	7 (32)	8 (36)
>40 yrs	13 (34.2)	10 (26.3)	8 (21)	7 (18.4)

*Totals do not add up to 61, because not all participants answered these questions in the questionnaire.

Results

- Older males tended to recall use of mobile phones better than younger participants and females
- Correlations noted in this study similar to previous reports
  - R=0.71 (minutes per day), $p<0.001$
  - R=0.69 (calls per day), $p<0.001$
- Monthly level reporting more accurate than daily or weekly
- Correlations did not differ much from year to year

Conclusion

- Recall of phone use is fair
- Bill records are needed to obtain accurate duration of exposure information

SMP Study

Study Objectives

- Assess factors potentially influencing RF of GSM phones
  - Geographic location
  - Urbanicity
  - Moving vs. stationary samples
  - Indoors vs. outdoors
  - User characteristics (e.g., hands-free)
  - Environmental factors (e.g., weather)

Methods

- Recruited volunteers
- 3 study areas (SAs):
  - SA1 – New Jersey
  - SA2 – New York City
  - SA3 – San Francisco area
- Survey Components
  - Software-modified phones (SMPs)
  - Log book
  - 5 days of logging phone calls
  - Questionnaire

Analysis

- Included only volunteers: >70% compliance (SMP and log book matched)
- Calculated average energy output per minute (J/min) per call
- Associations assessed within each of 3 SAs and all 3 combined
- Conducted ANOVA and post hoc tests before combining
- Multivariate, step-wise regression analysis

Results

- 2537 calls
- 53 subjects
- Compliance rate
  - NJ (college students): 77.7%
  - NYC (public): 82.8%
  - SF (professionals): 86.8%
- Most calls were within study areas

Energy Output: Analysis of Behavioral and Situation Variables

		SA1 (J/min)		SA2 (J/min)		SA3 (J/min)	
Predictor		Mean	P-value	Mean	P-value	Mean	P-value
Location	Inside	40.8	0.061	33.9	<0.001	27.1	0.0063
	Outside	35.7		22.6		20.4	
Urbanicity	Suburban	39.7	0.060	NA		23.6	0.694
	Urban	51.9				26.0	
Movement	Moving	34.2	0.001	19.7	0.001	19.6	<0.001
	Not moving	42.0		30.6		27.7	

Results

Step-wise regression analysis showed

1. SA - strongest predictor of energy output (explaining ~6% of variability)
2. Movement -next best predictor (~4% variability)
3. Location
4. Use of hands-free device
5. Urbanicity

These factors explain ~12% variability.

Factors with unclear effect on energy output

- Weather (limited data)
- Transportation (sparse data; modes not comparable)
- Place (sparse data over many categories)

Discussion

- **Movement affects energy output (J/min)**
  - **Stationary > Moving**
  - **GSM technology goes to max power at each handover**
  - **Expect more handovers and higher total energy while moving, particularly driving**
  - **Observed opposite finding**

Published in: Erdreich LS, Van Kerkhove MD, Scrafford CG, Barraj L, McNeely M, Shum M, Sheppard AR, Kelsh M. Factors that influence the radiofrequency power output of GSM mobile phones. Radiation Res 2007; 168(2):253–261.

Cell Phone Technology

Cell Phone Technologies

- 1 G – Analog
- 2 G – GSM, TDMA, CDMA
- 2.75 G – enhanced GSM
- 3 G – UMTS (W-CDMA), mainly CDMA
- 3.5 G – UMTS (HSDPA)
- 3.75 G
- 4 G – Flash OFDM, 3GPP LTE (upgrade UMTS)

1G

- Motorola Dynatac 8000X
- Analog
- 850 Hz

2G

- Motorola Timeport L7089
- GSM
- 900,1800,1900 MHz

2.75G

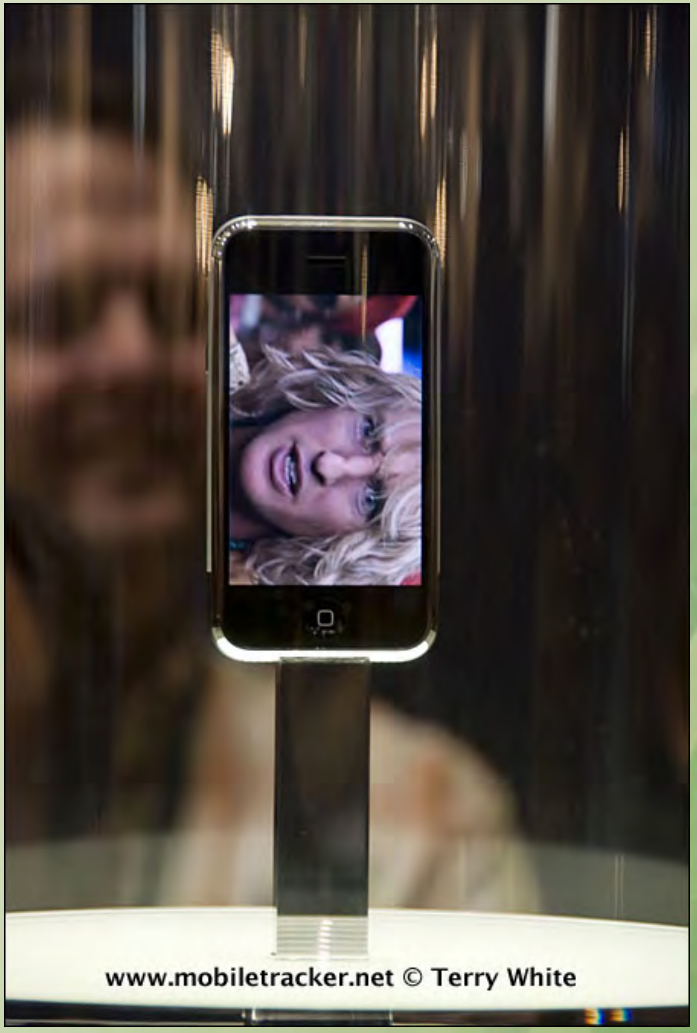
- 2.75 G
- Blackberry
- GSM
- 850, 900, 1800, 1900 MHz depending on model

3G

- Nokia 6650
- UMTS (W-CDMA)
- 850, 900,1800,1900 MHz

3.5G

- iPhone
- UMTS/HSDPA (850, 1900, 2100 MHz)
- GSM/EDGE (850, 900, 1800, 1900 MHz)
- Wi-Fi (802.11b/g)
- Bluetooth 2.0 + EDR

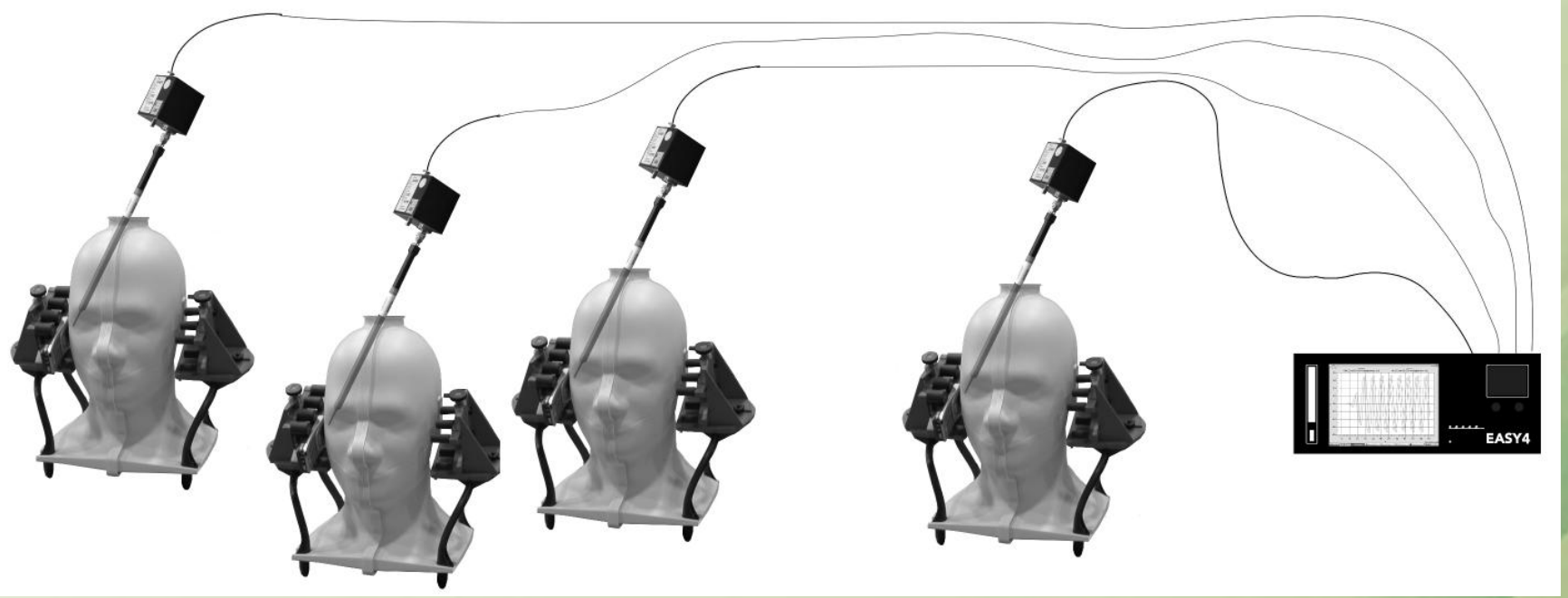


4G

- To be determined

Field Study

Instrumentation: SYNEHA



- One EASY4 allows data acquisition from probes at high sampling rates; PC-controlled
- IT'IS developed portable phantom system that could take readings from a car or van

Van Photos with SYNEHA and Phantoms

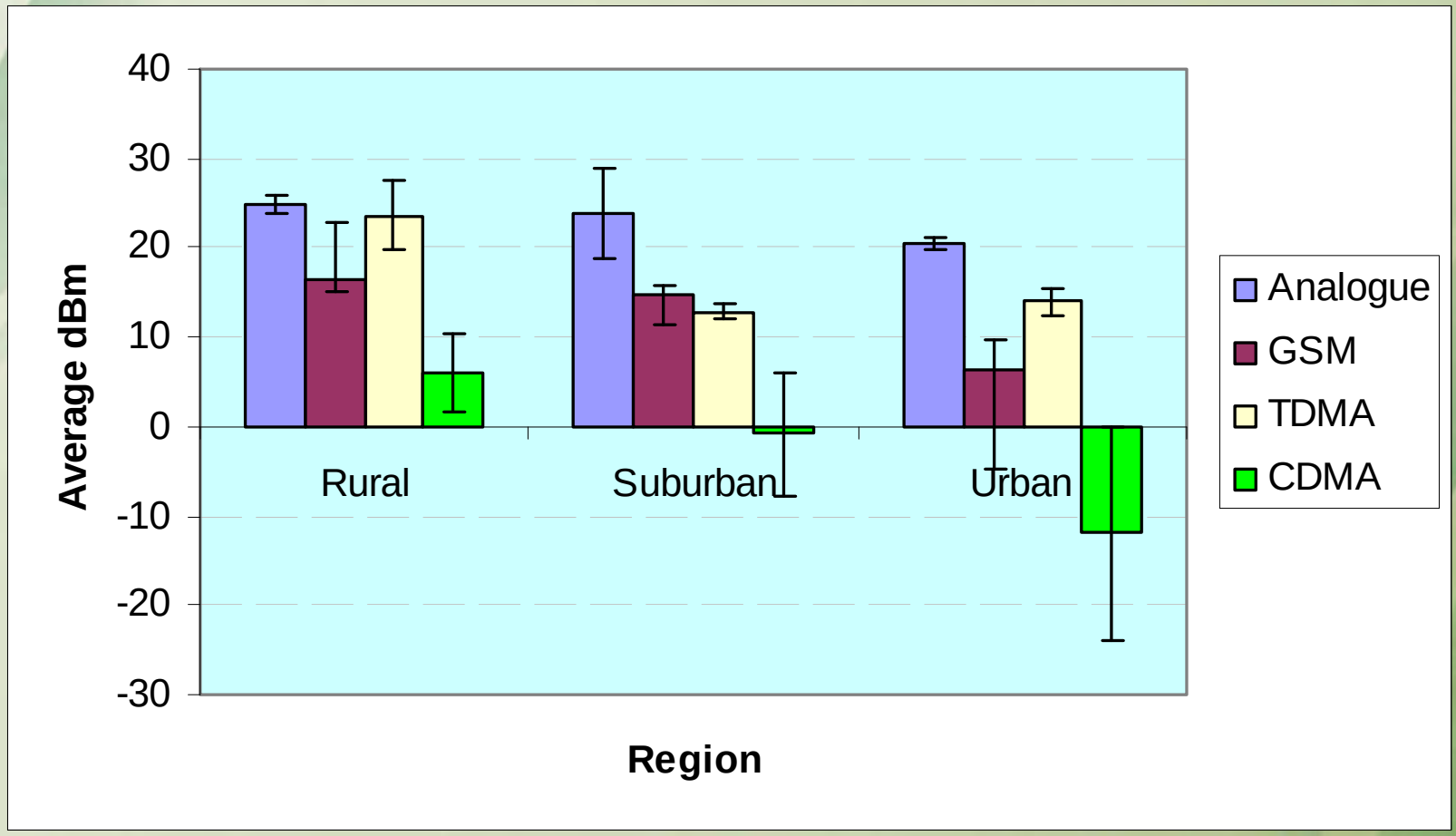
Parameters Evaluated

- Technology
  - GSM (1900 MHz),
  - CDMA, TDMA, and Analog (850 MHz)
- Type of Geographic Region (Proxy for Base station density)
  - Urban (San Francisco)
  - Suburban (Peninsula)
  - Rural
- Cellular traffic
  - Time of Day
- Type of phone
  - Flip/brick
  - Model

Average Power by Technology (dBm)

	Analog	CDMA	GSM	TDMA
N (trips)	22	92	68	26
Mean	22.34	-0.38	14.11	18.23
Median	24.10	2.36	15.36	16.10
Std. Dev.	3.02	8.24	5.40	5.37
Minimum	19.35	-17.26	-12.41	11.22
Maximum	29.01	13.43	17.66	25.88

Summary: Average Power By Technology and Route



ANOVA Results: Unbalanced Design

	DF	Total Sum of Squares	Mean Sum of Squares	F Value	P-Value
Technology	3	738.7	246.2	195.7	< 0.0001
Route	2	126.3	63.1	50.2	<0.0001
Technology * Route	6	43.5	7.3	5.8	<0.0001

Summary Results of Average Power (dBm) by GSM Phone Model

	Motorola V60 (Flip)	Timeport (SMP) (Candybar)	Nokia 5190 (Candybar)
N	8	41	8
Mean	24.09	23.84	21.94
Median	24.32	24.38	24.22
Std. Dev.	0.80	1.66	5.35
Minimum	22.26	19.64	9.67
Maximum	24.71	26.31	25.18

Federal Communications Commission Data

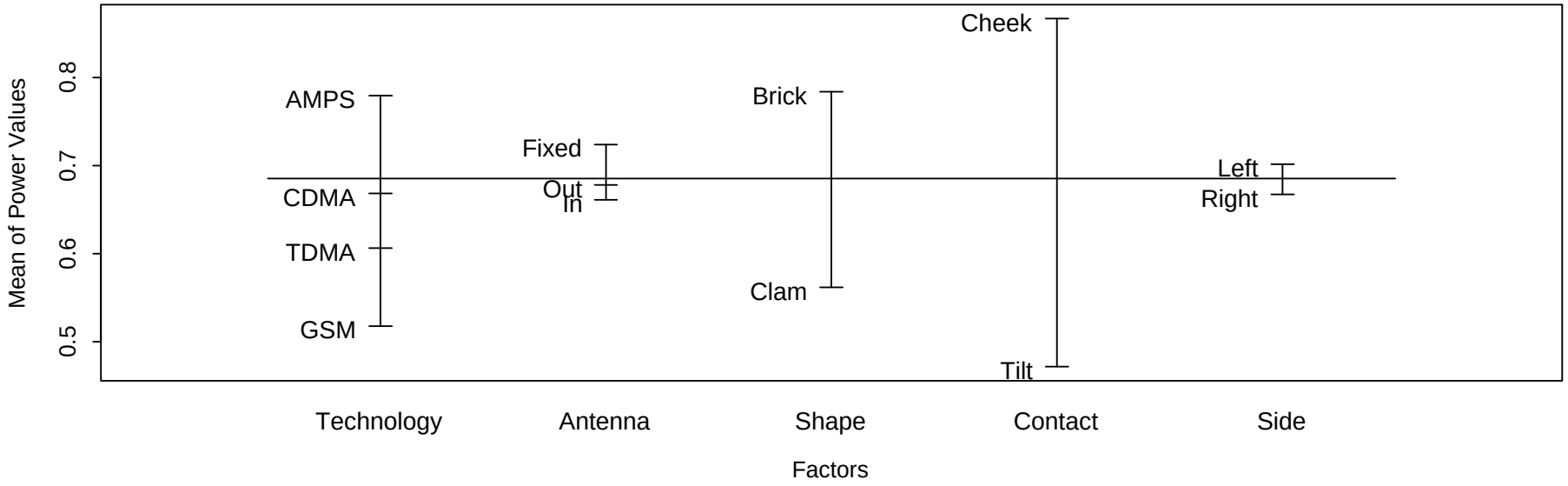
FCC Database

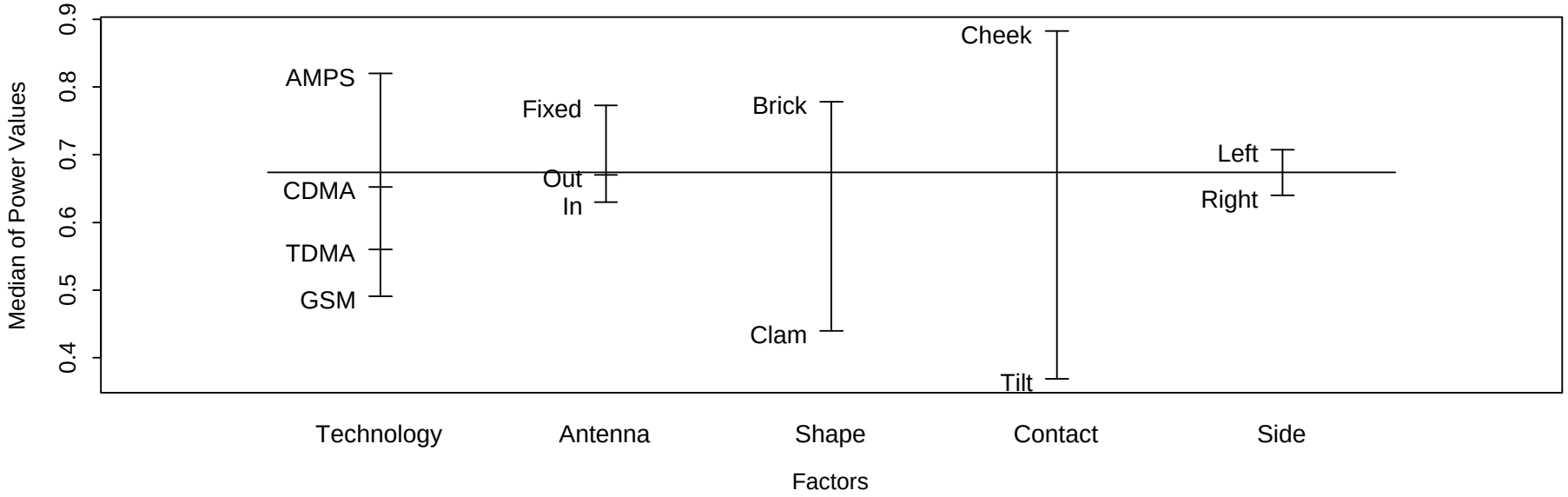
- FCC Requirements:
  - In the US, all cell phones are tested for RF emissions
  - Operated at maximum power output under specified standard test conditions
  - FCC limits – no greater than 1.6 W/kg Specific Absorption Rate (SAR)

- Methods:
  - Examined FCC database of results of compliance testing reports
  - Analyzed data for 2083 phones 1999-2005

800 MHz

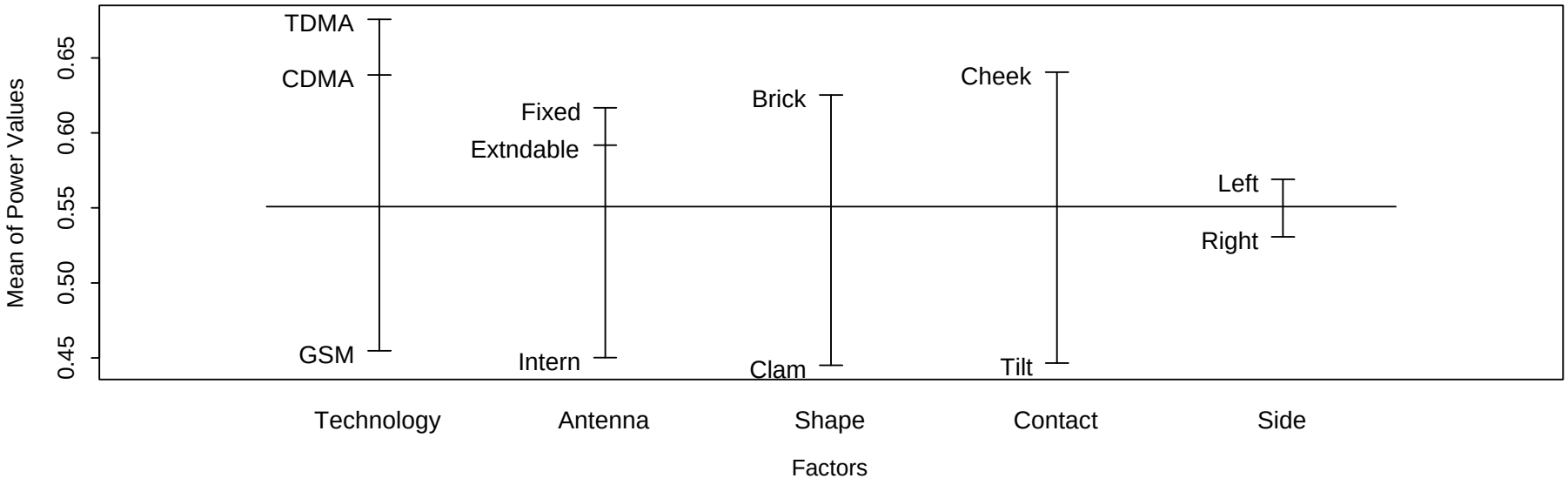
Plots of Means and Medians of Power Values at Levels of Five Factors
(Part 22)

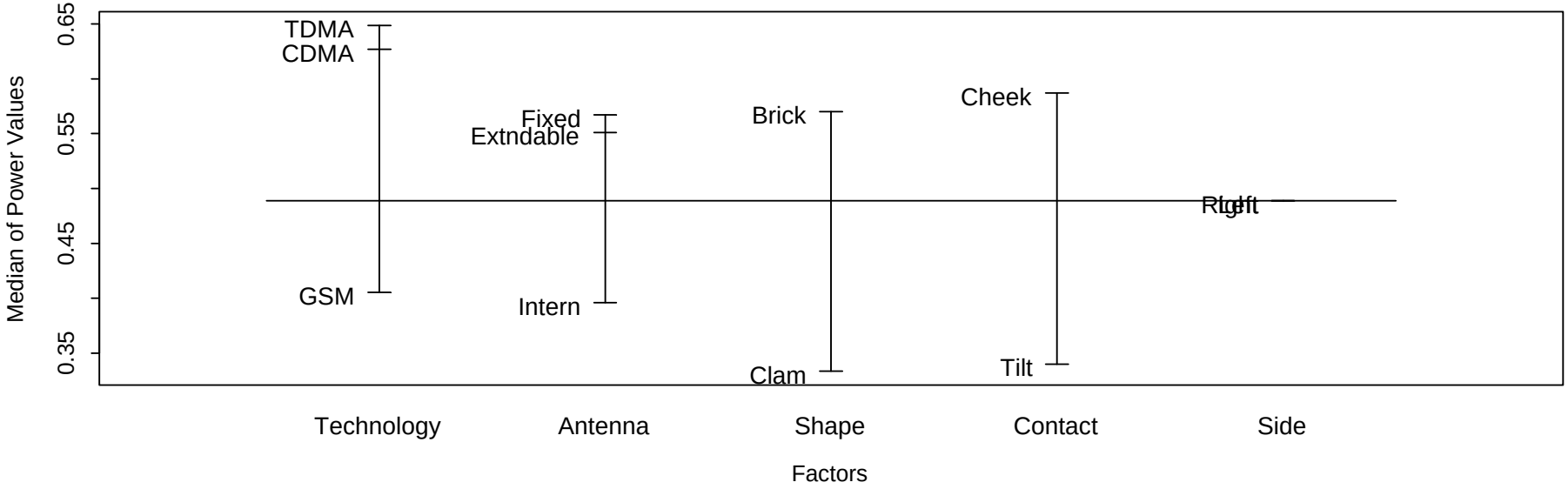




1900 MHz

Plots of Means and Medians of Power Values at Levels of Five Factors
(Part 24)





Rank Order

Field Testing (RF level)	FCC Testing (SAR)
Analog	Analog (only 800 MHz)
GSM	CDMA (800 Hz) TDMA (1900 Hz)
TDMA	CDMA (1900 Hz) TDMA (800 Hz)
CDMA	GSM

What does this all mean?

- CDMA when forced into highest output power, produces relatively high SAR levels
- GSM at highest output power level, in comparison produces the lowest SAR
- In the real world, CDMA hardly ever reaches this highest output level, whereas GSM goes to max power at each base station handover

Real world is different from the lab!

General Conclusions

- Recall of phone use is ok
- Technology has the biggest impact on RF exposure
- Urbanicity (which is a proxy for base station density) also impacts RF exposure
- Individual behavioural/environmental factors explain a small amount of variation in exposure

Implications for Health?

- Cell phone technology is moving to CDMA-based
- In real-world, CDMA technology produces much lower levels of RF than others
- Expect lower RF output levels than in the past
- Weak evidence that ≥ 10 years and ipsilateral use associated with increased brain tumours
  - More likely to have used analog phones
- It will be more difficult to find associations with health effects as phone technology improves

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Thank You

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Technology and Brain Tumours

	OR (95% CI)
Analog vs. unexposed	1.13 (0.83-1.54)
Digital vs. unexposed	0.86 (0.68-1.09)
Analog vs. Digital	1.22 (1.06-1.41)

Kan et al., 2008 – 5 studies cell phone type and brain tumours

Brain tumours

- **≥ 10 years use - OR: 1.25 (95%CI: 1.01-1.54) (Kan et al 2008)**
- **≥ 10 years and ipsilateral use (Hardell et al 2008)**
  - **glioma (OR: 2.0, 95%CI: 1.2-3.4)**
  - **acoustic neuroma (OR: 2.4, 95%CI: 1.1-5.3)**
  - **NOT meningioma (OR: 1.7, 95%CI: 0.99-3.1).**

Wi-Fi

- Uses OFDM – Orthogonal Frequency Multiplexing

Cordless Phones

- 900 MHz (older)
- 2.4 GHz
- 5.8 GHz
- Base stations closer (cradle)
- On average, much less power output than mobile phones

Blue Tooth

- Replaces RS232 cables
- Exchanges data over short distances from fixed and mobile devices
- Uses radio technology called frequency-hopping spread spectrum
- 2.4 GHz short-range radio frequency

Cell Phone Technologies

- Analog
- CDMA
- TDMA
- GSM