Environmental Research 165 (2018) 150–157

Contents lists available at ScienceDirect

Environmental Research

journal homepage: www.elsevier.com/locate/envres

Recall of mobile phone usage and laterality in young people: The multinational Mobi-Expo study

Geertje Goedhart[a,1], Luuk van Wel[a,*,1], Chelsea E. Langer[b,c,d], Patricia de Llobet Viladoms[b,c,d], Joe Wiart[e], Martine Hours[f], Hans Kromhout[a], Geza Benke[g], Evdoxia Bouka[h], Revital Bruchim[i], Kyung-Hwa Choi[j], Amanda Eng[k], Mina Ha[j], Anke Huss[a], Kosuke Kiyohara[l], Noriko Kojimahara[l], Daniel Krewski[m], Brigitte Lacour[n], Andrea 't Mannetje[k], Milena Maule[o], Enrica Migliore[o], Charmaine Mohipp[n], Franco Momoli[m,p,q], Eleni Th. Petridou[h], Katja Radon[r], Thomas Remen[s], Siegal Sadetzki[i,t], Malcolm Sim[g], Tobias Weinmann[r], Elisabeth Cardis[b,c,d], Martine Vrijheid[b,c,d], Roel Vermeulen[a]

[a] Institute for Risk Assessment Sciences (IRAS), Utrecht University, PO Box 80178, 3508 TD Utrecht, the Netherlands
[b] ISGlobal, Centre for Research in Environmental Epidemiology (CREAL), Barcelona, Spain
[c] Biomedical Research Centre Network for Epidemiology and Public Health (CIBERESP), Barcelona, Spain
[d] Universitat Pompeu Fabra (UPF), Barcelona, Spain
[e] Chaire C2M, LTCI, Telecom ParisTech, Université Paris-Saclay, France
[f] Epidemiological Research and Surveillance Unit in Transport, Occupation and Environment (UMRESTTE), Université de Lyon/The French Institute of science and technology for transport, development and networks (IFSTTAR), Lyon, France
[g] Department of Epidemiology & Preventive Medicine, School of Public Health & Preventive Medicine, Monash University, Melbourne, Australia
[h] Department of Hygiene, Epidemiology and Medical Statistics, Medical School, National and Kapodistrian University of Athens, Athens, Greece
[i] Cancer and Radiation Epidemiology Unit, Gertner Institute for Epidemiology and Health Policy Research, Chaim Sheba Medical Center, Tel Hashomer, Israel
[j] Department of Preventive Medicine, Dankook University College of Medicine, Cheonan, Republic of Korea
[k] Centre for Public Health Research, Massey University, Wellington, New Zealand
[l] Department of Public Health, Tokyo Women's Medical University, Tokyo, Japan
[m] School of Epidemiology and Public Health, University of Ottawa, Canada
[n] French National Registry of Childhood Solid Tumours, CHU, Nancy, Inserm UMRS-1153, CRESS-EPICEA, University of Paris-Sorbonne, Paris, France
[o] Cancer Epidemiology Unit, Department of Medical Sciences, University of Turin and AOU Città della Salute e della Scienza di Torino, Italy
[p] Children's Hospital of Eastern Ontario Research Institute, University of Ottawa, Canada
[q] Ottawa Hospital Research Institute, Canada
[r] Occupational and Environmental Epidemiology & NetTeaching Unit, Institute and Outpatient Clinic for Occupational, Social and Environmental Medicine, University Hospital of Munich (LMU), Munich, Germany
[s] French National Registry of Childhood Solid Tumours, CHU, Nancy, France
[t] Sackler Faculty of Medicine, Tel Aviv University, Tel Aviv, Israel

ARTICLE INFO

Keywords:
Laterality
Mobile application
Adolescent
Child
Validation study
Mobile phone use

ABSTRACT

Objective: To study recall of mobile phone usage, including laterality and hands-free use, in young people.
Methods: Actual mobile phone use was recorded among volunteers aged between 10 and 24 years from 12 countries by the software application XMobiSense and was compared with self-reported mobile phone use at 6 and 18 months after using the application. The application recorded number and duration of voice calls, number of text messages, amount of data transfer, laterality (% of call time the phone was near the right or left side of the head, or neither), and hands-free usage. After data cleaning, 466 participants were available for the main analyses (recorded vs. self-reported phone use after 6 months).
Results: Participants were on average 18.6 years old (IQR 15.2–21.8 years). The Spearman correlation coefficients between recorded and self-reported (after 6 months) number and duration of voice calls were 0.68 and 0.65, respectively. Number of calls was on average underestimated by the participants (adjusted geometric mean ratio (GMR) self-report/recorded = 0.52, 95% CI = 0.47–0.58), while duration of calls was overestimated (GMR = 1.32, 95%, CI = 1.15–1.52). The ratios significantly differed by country, age, maternal educational level, and level of reported phone use, but not by time of the interview (6 vs. 18 months). Individuals who

* Corresponding author.
E-mail address: l.vanwel@uu.nl (L. van Wel).
[1] These authors contributed equally.

https://doi.org/10.1016/j.envres.2018.04.018
Received 29 November 2017; Received in revised form 16 April 2018; Accepted 18 April 2018
Available online 26 April 2018
0013-9351/

reported low mobile phone use underestimated their use, while individuals who reported the highest level of phone use were more likely to overestimate their use. Individuals who reported using the phone mainly on the right side of the head used it more on the right (71.1%) than the left (28.9%) side. Self-reported left side users, however, used the phone only slightly more on the left (53.3%) than the right (46.7%) side. Recorded percentage hands-free use (headset, speaker mode, Bluetooth) increased with increasing self-reported frequency of hands-free device usage. Frequent (≥50% of call time) reported headset or speaker mode use corresponded with 17.1% and 17.2% of total call time, respectively, that was recorded as hands-free use.

Discussion: These results indicate that young people can recall phone use moderately well, with recall depending on the amount of phone use and participants' characteristics. The obtained information can be used to calibrate self-reported mobile use to improve estimation of radiofrequency exposure from mobile phones.

1. Introduction

The rapid worldwide increase in mobile phone use has led to increased concern about potential health effects due to exposure to radiofrequency (RF) fields. Additionally, mobile phone use has changed dramatically in recent years with both the introduction of third and fourth generation cellular networks as well as continuously evolving smartphone hardware and software. Potential health effects (if they exist) related to RF fields originating from mobile phones would likely be greater among young people for various reasons. The neurological system of children is still developing and may be more sensitive to effects of RF, the distribution of RF absorption across the brain may be different compared to adults, and the specific absorption rate (SAR) in the most exposed part of the brain tend to be higher in children than it is in adults (Wiart et al., 2011). Lastly, the lifetime exposure of children to RF from mobile phones will be larger as they start using a mobile phone at a young age compared to current adults. Several national and international bodies have recommended studies of exposure in childhood and adolescence as high priority RF research areas due to this (Kheifets, 2005). As a result, two large multinational case-control studies were set up, the CEFALO study in four (Northern) European countries (Aydin et al., 2011c), and the MOBI-Kids study in 14 countries, both within and outside Europe (Sadetzki et al., 2014). In addition several national studies were set up, including the HERMES study in Switzerland (Schoeni et al., 2015), and the SCAMP cohort study in the United Kingdom (Mireku et al., 2018), looking at cognitive and behavioural outcomes.

Exposure assessment within epidemiological studies on health effects of mobile phone use generally relies on participants' recall of their mobile phone use. Previous validation studies among children and adolescents have found that this recall comes with substantial random and systematic errors (Aydin et al., 2011a; Goedhart et al., 2015b; Inyang et al., 2010, 2009; Kiyohara et al., 2016; Redmayne et al., 2012), which can lead to under- or overestimation of the explored health risks (Aydin et al., 2011b; Vrijheid et al., 2006a, 2006b). As part of MOBI-Kids, a case-control study exploring the potential effects of childhood and adolescent exposure to electromagnetic fields from mobile communications technologies on brain tumour risk (Sadetzki et al., 2014), the Mobi-Expo validation study was performed to study recall of mobile phone use among young people from 12 out of 14 countries. This is the largest multinational validation study to date. A software application (app) was developed by Whist Lab (Paris, France) to be installed on participants' own smartphone or a study phone (Goedhart et al., 2015b). In addition to duration and frequency of calls and text messages, the app also recorded information regarding laterality, hands-free usage, and data transfer. We report here the results of mobile phone usage and use behaviour recall at 6 and 18 months after the use of the app by study individuals. In addition, we explore if the observed differences in recall are related to demographic variables and/or phone usage.

2. Methods

From October 2012 to August 2014, volunteers between 10 and 24 years old were recruited in 12 MOBI-Kids countries: Australia, Canada, France, Germany, Greece, Israel, Italy, Japan, Korea, New Zealand, Spain and the Netherlands. The study was approved by the Institutional Review Boards in each country; all volunteers and/or their legal guardians provided informed consent following the country-specific protocols, including parental consent if indicated. More details about the recruitment procedures in each country are described in the paper by Langer et al. (2017).

2.1. Participants

Two types of participants were enrolled in the study. The first type of participants were those who owned a smartphone using the Android operating system (OS) (60% of total study population). The second type (40%), who did not own a smartphone using the Android OS, received a study phone (either a Samsung Galaxy Mini or a Galaxy S2) for four weeks. These participants were instructed to insert their own SIM card into the study phone and use it just as they would use their own phone. All participants installed the XMobiSense application (app) on the smartphone. After four weeks of data collection, data were either automatically transferred to a server or a data file was created by the participant or study coordinator. Four countries only recruited participants who owned their own smartphone using the Android OS: Greece, Japan, Korea and New Zealand while the other eight countries recruited a mix of the first and second type of participants.

2.2. Recorded mobile phone use (XMobiSense)

Whist Lab (Paris, France) developed a smartphone app called "XMobiSense", which can be installed on any smartphone using the Android OS. This app records date, time, and duration (in seconds) of voice calls, laterality (right/left side) of use (hands-free while using a device (i.e.: wired headset, speaker mode, Bluetooth headset/car kit), and other hands-free without using a device (e.g., answering/ending a call)), number of text messages sent and received, amount of data transfer (in bytes), and the communication system and technology used for voice calls (2G/3G) and data transfer (WiFi, GPRS, EDGE, UMTS, HSDPA, and other). No personal information or call/text content was recorded by the app. After piloting the app and study protocol (Goedhart et al., 2015b), some errors were observed in the recording of laterality and 'other hands-free use' for some devices. As such, only the following phone models were included in the current analyses on laterality and hands-free usage: Samsung Galaxy Ace, S (Plus), S2, S3, S3 (mini), S4, and S4 (mini).

2.3. Self-reported mobile phone use

Before participants started to use the app, a baseline questionnaire (Q1, 0 months) was completed (either face to face (64%), by phone (27%), or by (e)mail (9%)). The questionnaires included socio-demographic questions (parental education), and questions regarding current mobile phone use (frequency and duration of calls and number of text messages, laterality, hands-free use, proportion of use in urban/

rural areas, sending e-mail, video, or files, hotspot and other data use, and voice over IP calling) over the past three months. Answers on questions concerning frequency and duration of mobile phone uses were collected as open-ended responses (e.g.: minutes per day). The actual questionnaires can be found in the supplementary materials C.

After the 4-week period of data collection by the app, participants who borrowed a study phone completed a change-of-use questionnaire (Q2, 1 month) upon returning the study phone either face to face (84%), by phone (14%), or by (e)mail (2%).

Six months after data collection ended, a validation questionnaire (Q3, 6 months) was administered to both types of study participants by phone (76%), face to face (13%) or by (e)mail (11%). In this validation questionnaire, participants were asked to make an estimation of their mobile phone use during the 4-week period of data collection by the app. Questions included number and duration of voice calls, number of text messages sent, laterality (the side of the head one generally held the phone: left, right or both sides), hands-free device usage (wired headset, speaker mode of the phone, car kit, and/or Bluetooth headset), and time spent using the Internet. The question on number of text messages sent included both text messages (i.e., short messages service (SMS)) and WhatsApp messages in the baseline questionnaire. For Germany and Japan WhatsApp messages were also included in the Q3 questionnaires, but not for the other countries. As a result, these two countries were excluded from the analyses comparing self-reported to recorded number of text messages as the app did not record WhatsApp messages specifically as this was part of data use.

In five countries (Australia, Israel, Italy, Spain, and the Netherlands), the validation questionnaire was administered again at 18 months after using the app (Q4, 18 months) (face to face (4%), by phone (82%), by (e)mail (14%)). The study timeline can be found in Supplementary Fig. B.1.

2.4. Study participation

A total of 587 participants used the XMobiSense application. 53 participants were excluded after errors were found in a substantial proportion of their call registration (i.e.: > 5% of calls either had a duration of 0 s or over 4 h). An additional participant was excluded for having less than 8 days' worth of usable log files, bringing the number of included participants for our analyses to 533 (90.8% of recruited XMobiSense users). From these 533 participants, 466 (79.4%) successfully completed both the baseline questionnaire (Q1) and the validation questionnaire after 6 months (Q3) on the amount of calls and duration of calls. Among these, 190 also completed the questionnaire 18 months after using the app (Supplementary Fig. B.2).

For the analyses on laterality and hands-free usage 229 participants who used phone models that performed accurately in laterality tests were included.

2.5. Statistical analyses

Volunteers with at least 8 days of usable XMobiSense log file data were included in the analyses. Recorded and self-reported number of voice calls and number of text messages sent were calculated per week, and duration of calls in minutes per week. Agreement between self-reported and recorded number and duration of calls and number of text messages sent was explored with Spearman correlations, Bland-Altman plots, and adjusted geometric mean ratios (self-reported/recorded). Multivariable analyses included the following covariates: country, age, gender, maternal educational level, type of phone user (type I: own phone vs. type II: borrowed study phone using their own SIM card), time period, and level of reported phone use. All covariates were used in one model for mutual adjustment and to calculate the adjusted geometric mean ratios. The maternal educational level was categorized into low (secondary/high school or less), medium (graduate of medium level technical/professional school), high (university/high level technical school or postgraduate university), and unknown. Recorded data transfer was calculated in megabytes (MB) per week, while self-reported total time spent using the Internet in minutes per week; the correlation between the variables was explored with the Spearman correlation. Recorded laterality (right/left side) and hands-free device usage (headset, Bluetooth, and speaker mode use) were calculated in percentages of total call time. Hands-free usage without a device (i.e.: regular call mode, but not near the head) was not included in hands-free usage as it usually represents the time between answering/ending a call and moving the phone to/from the head. The mean percentages of total call time were then derived for each category of self-reported laterality or hands-free device usage. Self-reported hands-free device users were divided into low (less than half the call time) and high (half or more of the call time) frequency users. Logistic regression analyses were performed to explore the influence of covariates on the agreement between self-reported and recorded laterality and hands-free device usage. All analyses were performed in SPSS Statistics Version 24.

3. Results

Participants were on average 18.6 years old (interquartile range 15.2 – 21.8 years), 37% were male, and 47% of the individuals' mothers had attained the highest level of education. The patterns in recorded mobile phone use are described in more detail by Langer et al. (2017). In summary, higher recorded call number and duration were found among females, and in the oldest age group. Age and country explained a large part of the variance in recorded phone use characteristics, with gender, maternal education and study period explaining additional but smaller parts of the variance found.

3.1. Voice calls

The Spearman correlation coefficient between self-reported (after 6 months) and recorded number of voice calls was 0.68. On average, participants underestimated the number of calls made and received with a geometric mean ratio (GMR; self-reported to recorded) of 0.52 (95% confidence interval (CI) 0.47–0.58) (Table 1). As the recorded number of calls includes unsuccessful calls (i.e., no connection), while these are likely not included in the self-reported information, we performed a sensitivity analysis excluding potentially unsuccessful calls (defined as outgoing calls of 0–10 s) from the recorded information. This analysis resulted in a slight increase in the GMR to 0.59 (95% CI 0.53–0.66). Multivariable analyses showed that the ratio for number of calls significantly decreased with increasing age (i.e., younger children reported better than adolescents) and increased with increasing maternal educational level (Table 1). Individuals who reported low mobile phone use underestimated their use, while individuals who reported the highest level of phone use were more likely to overestimate their use; this is also illustrated in the Bland-Altman plot, where the relative difference between self-reported vs recorded calls (y-axis) changes from a negative difference at lower levels to a positive difference at higher levels of self-reported use (x-axis) (Figs. A.1, A.2, A.3 Supplementary materials). Individuals who used their own phone reported better than study phone users (Table 1). Furthermore, individuals from Greece and Korea had the highest underestimation of use, while individuals from Australia and Japan had the lowest underestimation of use (Table 1). The GMRs did not differ significantly by gender and time period (Table 1).

The Spearman correlation coefficient between self-reported (after 6 months) and recorded duration of time spent on voice calls was 0.65. The duration was on average overestimated by the participants with a GMR of 1.32 (95% CI 1.15–1.52) (Table 1). Excluding the potentially unsuccessful calls from the recorded information had no effect on the GMR. Multivariable analyses showed that the GMR significantly decreased with age, with an overestimation of call duration among the younger age groups (10–19 y) and underestimation among young adults

(20–24 y) (Table 1). The GMRs significantly increased with maternal educational level (i.e., a lower educational level was linked to a better estimation) and with level of reported phone use, that is, individuals who reported high mobile phone use overestimated their use, and individuals reporting low phone use underestimated their use (Table 1) (illustrated in the Bland-Altman plot, Figure 1 Appendix). The level of overestimation was higher for individuals who used their own phone compared to study phone users. Individuals from Japan, Australia, and Spain overestimated their time spent on voice calls most, while individuals from Greece, Israel and Korea were more likely to underestimate this. There was no significant difference in GMRs by gender and time period (Table 1).

3.2. Text messages

The Spearman correlation coefficient between self-reported and recorded number of text messages sent was 0.73. Participants on average overestimated the number of text messages they had sent (GMR = 1.18; 95% CI 0.95–1.47) when recalling this after 6 months (Table 1). Multivariable analyses showed that the GMR significantly differed by country, with individuals from Spain and Greece having the highest level of overestimation, while individuals from Canada and France underestimated the number of text messages sent (Table 1). Furthermore, overestimation was seen among individuals who reported sending a high number of text messages, while lower level users underestimated their number of text messages sent (see also Bland-Altman plot, Fig. 1 Appendix).

Table 1
Adjusted geometric mean ratio of self-reported (after 6 months) versus recorded number and total duration of calls and number of text messages sent (adjusted for the other variables in the table).

	Number of calls			Total duration of calls			Number of text messages sent		
	N	GMR[a]	95% CI	N	GMR[a]	95% CI	N	GMR[a]	95% CI
Overall	**466**	**0.52**	**0.47–0.58**	**466**	**1.32**	**1.15–1.52**	**422**	**1.18**	**0.94–1.47**
Country									
Australia	29	0.88	0.59–1.29	29	2.74	1.66–4.54	28	1.57	0.70–3.52
Canada	32	0.60	0.43–0.83	32	1.27	0.82–1.95	32	0.43	0.21–0.89
France	42	0.41	0.30–0.58	42	1.16	0.75–1.79	42	0.45	0.22–0.92
Germany	15	0.49	0.32–0.76	15	1.09	0.62–1.91	*na*[b]	*na*	*na*
Greece	41	0.31	0.21–0.48	41	0.56	0.33–0.96	41	2.46	1.06–5.73
Israel	38	0.40	0.29–0.55	38	0.89	0.60–1.33	35	1.52	0.81–2.85
Italy	56	0.38	0.29–0.52	56	1.07	0.73–1.58	55	0.76	0.40–1.46
Japan	22	0.96	0.64–1.43	22	3.61	2.16–6.04	*na*[b]	*na*	*na*
Korea	49	0.34	0.25–0.46	49	0.71	0.48–1.05	48	0.99	0.52–1.87
New Zealand	19	0.61	0.36–1.05	19	1.05	0.52–2.14	19	0.83	0.27–2.54
Spain	45	0.61	0.45–0.82	45	2.52	1.71–3.71	45	4.34	2.22–8.48
The Netherlands	78	0.65	0.50–0.84	78	1.78	1.27–2.50	77	1.69	0.97–2.92
		P[†] < 0.01			P[†] < 0.01			P[†] < 0.01	
Age									
10–14 years	109	0.72	0.60–0.85	109	2.22	1.77–2.78	104	1.27	0.90–1.79
15–19 years	166	0.50	0.43–0.58	166	1.32	1.09–1.59	154	1.14	0.85–1.54
20–24 years	191	0.40	0.34–0.46	191	0.79	0.67–0.95	164	1.13	0.83–1.53
		P[†] < 0.01			P[†] < 0.01			P[†] = 0.87	
Gender									
Male	175	0.54	0.47–0.62	175	1.43	1.19–1.71	159	1.31	0.98–1.75
Female	291	0.51	0.45–0.57	291	1.23	1.04–1.44	263	1.06	0.82–1.38
		P[†] = 0.41			P[†] = 0.14			P[†] = 0.21	
Maternal education									
Low	99	0.49	0.41–0.59	99	1.24	0.98–1.55	88	1.30	0.91–1.86
Medium	113	0.60	0.51–0.71	113	1.50	1.21–1.86	100	1.14	0.80–1.61
High	219	0.62	0.54–0.71	219	1.69	1.42–2.01	209	1.04	0.82–1.32
Unknown	*35*	*0.41*	*0.31–0.53*	*35*	*0.98*	*0.69–1.38*	*25*	*1.26*	*0.67–2.35*
		P[†] < 0.01			P[†] = 0.01			P[†] = 0.74	
Type of phone user									
Study phone	184	0.43	0.37–0.50	184	1.13	0.92–1.38	178	1.00	0.74–1.36
Own phone	282	0.63	0.55–0.72	282	1.55	1.31–1.84	244	1.39	1.03–1.87
		P[†] < 0.01			P[†] = 0.01			P[†] = 0.12	
Time period of recruitment									
Oct 2012 – March 2013	105	0.47	0.36–0.61	105	1.03	0.73–1.45	101	0.94	0.53–1.67
April – Sept 2013	105	0.47	0.37–0.60	105	1.17	0.85–1.61	94	1.89	1.08–3.33
Oct 2013 – March 2014	200	0.52	0.43–0.62	200	1.37	1.08–1.74	171	1.40	0.92–2.12
April – July 2014	56	0.64	0.41–1.02	56	1.86	1.02–3.38	56	0.77	0.31–1.93
		P[†] = 0.77			P[†] = 0.48			P[†] = 0.11	
Level of reported mobile phone use[c]									
< 20th percentile	87	0.21	0.17–0.25	87	0.34	0.27–0.43	91	0.21	0.14–0.32
20th–40th percentile	68	0.32	0.26–0.39	102	0.75	0.59–0.94	84	0.65	0.43–0.98
40th–60th percentile	90	0.50	0.42–0.60	87	1.29	1.01–1.64	81	1.36	0.93–1.97
60th–80th percentile	115	0.79	0.67–0.93	98	2.37	1.87–2.99	83	2.30	1.55–3.43
> 80th percentile	106	1.50	1.24–1.80	92	5.24	4.08–6.70	83	5.29	3.53–7.94
		P[†] < 0.01			P[†] < 0.01			P[†] < 0.01	

Median duration of calls per level: < 20th: 4.7 min/wk; 20th-40th: 15.9; 40th–60th: 43.8; 60th-80th: 109.7; > 80th : 391.0.
Median number of text messages per level: < 20th: 0.7 p/wk; 20th-40th: 4.9; 40th-60th: 17.8; 60th–80th: 64.3; > 80th : 398.4.
[a] Adjusted geometric mean ratio (GMR) of self-reported to recorded information (adjusted for the other variables in the table).
[b] Number of self-reported text messages not applicable for Germany and Japan, because it included WhatsApp messages.
[c] Median number of calls per level: < 20th: 1.9 calls/wk; 20th–40th: 4.6; 40th–60th: 8.8; 60th–80th: 19.7; > 80th: 69.5.
[†] P-values of F-ratio indicating whether the mean values differ.

3.3. Recall

Comparing the recall among individuals who had questionnaires available from all three time points (before use (0 months), 6 and 18 months after use) showed an initial lapse in recall between the initial timepoint (GMR 0.64) and 6 months later (GMR 0.53), but relatively small differences between 6 months and 18 months (GMR 0.51) (Table 2). For both the number and total duration of calls the GMR at 6 and 18 months after use was slightly lower than the GMR at 0 months (comparing the baseline questionnaire versus the recorded data in the month thereafter). For number of text messages sent the GMR was somewhat lower at 18 months compared to 6 months after use; comparison with the GMR at 0 months was not possible, as text messages in the baseline questionnaire included WhatsApp messages. Recall at 6 and 18 months was focused on mobile phone use during the data collection period, while the baseline (0 months) interview focused on the three months beforehand. Although these are differing recall periods, we assumed that mobile phone use during the three months before data collection is representative for the data collection period

3.4. Data use

We observed a Spearman correlation coefficient of 0.39 between self-reported (after 6 months) time spent using the Internet and recorded amount (bytes) of data transferred. About 10% of the participants reported not having used the Internet, even though data transfer was recorded by the app.

When looking at recorded amount of data, on average 72.5% (IQR 53.2–99.1%) was transferred over WiFi.

3.5. Laterality

When comparing self-reported and recorded laterality, analyses were performed with and without the recorded call time where the phone was away from the head (Table 3). The latter analysis was included to better illustrate the comparison with self-reported laterality, where time away from the head was not included as an option in the questionnaire. When considering only the call time close to the head, self-reported right side users (at 6 months) actually used the phone on average for 70.8% of the call time on the right side of the head, while self-reported left side users used it for only 53.3% on the left side of the head. Participants who reported using the phone on both sides of the head actually used it on average more on the right (56.6%) than the left side (43.4%). Multivariable analyses showed that the level of recorded mobile phone use had a significant impact on the agreement between self-reported laterality at 6 months and recorded laterality (defined as ≥75% at the right or left side, otherwise both sides), with individuals in the > 80th percentile of phone use having lower odds for agreement compared to individuals in the < 20th percentile of phone use (odds ratio = 0.48). Other covariates did not have a significant impact on the agreement (data not shown).

In addition, the consistency of self-reported laterality over time (before versus 6 and 18 months after using the app) is shown in Table 4. Participants who reported using the phone mainly on the right side of the head appeared to be most consistent in their report over time. Individuals who reported mainly left or both sides were more likely to shift over time.

Table 3
Laterality: self-reported (after 6 months) versus recorded.

Self-reported	Recorded (% of total call time)			
	N (%)[a]	Mean % right side (SD)	Mean % left side (SD)	Mean % away from the head (SD)[b]
Mainly right side	158 (69.9)	**58.8 (25.4)**	22.7 (18.9)	18.5 (17.6)
Mainly left side	41 (18.1)	32.2 (23.7)	**43.4 (28.5)**	24.4 (28.6)
Both sides	27 (11.9)	41.2 (25.8)	32.5 (25.1)	26.3 (30.1)
Unknown	*3*			
Excluding % of total call time away from the head				
Mainly right side	158 (69.9)	**70.8 (24.4)**	29.2 (24.4)	
Mainly left side	41 (18.1)	45.9 (27.8)	**54.1 (27.8)**	
Both sides	27 (11.9)	56.6 (25.0)	43.4 (25.0)	
Unknown	*3*			

[a] Included only phone models that accurately performed in the laterality tests. 3 individuals were missing self-reported laterality information, resulting in N = 226.

[b] The phone was not near the head during a voice call, e.g., hands-free device usage, answering/ending a call.

3.6. Hands-free use

The recorded percentage of hands-free use increased with increasing self-reported frequency of hands-free device usage after 6 months (Table 5). For headset and speaker mode use, the recorded percentages of hands-free use significantly differed by self-reported usage levels. Among participants who reported no use of headset, speaker mode or Bluetooth in the questionnaire, recorded hands-free use was 3.2%, 3.8%, 0.2% of total call time, respectively. High frequent report (≥50% of call time) of headset or speaker mode use (high frequent use was not reported for Bluetooth) corresponded to 17.1% and 17.2% of total call time, respectively, that was recorded as hands-free use. Multivariable analyses showed no significant effect of explored covariates on the agreement between self-reported hands-free device usage at 6 months (no/yes) and recorded percentage hands-free use (no/yes, with yes being defined as > 0.01% of total call time) (data not shown). When comparing self-reported hands-free device usage over time (before versus 6 and 18 months after using the app), participants who reported no (wired) headset or Bluetooth use were most consistent in their report over time (Table 6).

Table 2
Geometric mean ratio of self-reported versus recorded number and total duration of calls, and number of text messages sent, by time of self-report.

		Time of self-report					
		Before (0 months)		After 6 months		After 18 months	
	N[a]	GMR	95% CI	GMR	95% CI	GMR	95% CI
Number of calls	190	0.64	0.56–0.73	0.53	0.46–0.61	0.51	0.44–0.59
Total duration of calls	190	1.64	1.40–1.92	1.44	1.21–1.72	1.43	1.20–1.71
Number of text messages sent	167	*na*[b]	*na*[b]	1.10	0.87–1.40	0.94	0.72–1.24

[a] Included only individuals who had questionnaire data available for all three (or two in the case of text messages) time points.

[b] Text messages from baseline questionnaire (0 months) included WhatsApp messages.

Table 4
Laterality: self-reported compared over time (before, and after 6 and 18 months).

	Before (0 months)			
	Mainly right side, N (%)	Mainly left side, N (%)	Both sides, N (%)	*Unknown N*
After 6 months				
Mainly right side	**119 (85%)**	8 (26.7%)	8 (44.4%)	
Mainly left side	11 (7.9%)	**22 (73.3%)**	5 (27.8%)	
Both sides	10 (7.1%)	0 (0.0%)	**5 (27.8%)**	
Unknown				*2*
After 18 months				
Mainly right side	**118 (84.3%)**	6 (20.0%)	11 (61.1%)	
Mainly left side	9 (6.4%)	**21 (70.0%)**	2 (11.1%)	
Both sides	13 (9.3%)	3 (10.0%)	**5 (27.8%)**	
Unknown				*2*

Included only individuals who had self-reported laterality data available for all three time points (N = 190).

Table 5
Hands-free device usage: self-reported (after 6 months) versus recorded.

Self-report	Recorded (% of total call time)		
	N (%)*	Mean % headset use (SD)	P†
Headset (wired)			
No	173 (76.2)	3.2 (10.0)	< 0.01
Yes, low frequency	43 (18.9)	8.5 (15.6)	
Yes, high frequency	11 (4.8)	17.1 (22.8)	
	N (%)*	Mean % speaker mode use (SD)	P†
Speaker mode			
No	139 (61.2)	3.8 (80)	< 0.01
Yes, low frequency	75 (33.0)	9.7 (12.5)	
Yes, high frequency	13 (5.7)	17.2 (17.4)	
	N (%)*	Mean % Bluetooth use (SD)	P†
Bluetooth (headset, car kit)			
No	216 (95.2)	0.2 (1.7)	0.19
Yes, low frequency	11 (4.8)	0.9 (2.9)	
Yes, high frequency	0 (0)	–	

* Included only phone models that performed accurately in the laterality tests. 2 individuals were missing self-reported information, resulting in N = 227.
† P-values of F-ratio indicating whether the mean values differ.

4. Discussion

This large, multinational study on recall in young participants compared self-reported mobile phone use with software application-recorded mobile phone use. Recall errors were found for both number and duration of voice calls, with ratios significantly differing by country, age, educational level, and level of reported phone use, but not by time of interview. Systematic errors were found, with the number of calls underestimated by a factor of 0.52 on average, and the duration of calls and number of text messages sent overestimated by factors of 1.32 and 1.18, respectively. Individuals with low mobile phone use tended to underestimate their use, while individuals with the highest level of mobile phone use were more likely to overestimate their use. In addition, substantial random error was found, which is likely to affect risk estimates.

Previous validation studies among young people observed an overestimation of duration of calls, although the level of overestimation differed between studies (Aydin et al., 2011a; Goedhart et al., 2015b; Kiyohara et al., 2016; Mireku et al., 2018). Earlier findings with regard to recall of number of calls among young people are less consistent: (Aydin et al., 2011a) compared operator records with self-reports and found that individuals overestimated the number of calls, while the SCAMP study found an underestimation of call frequency (Mireku et al., 2018). Other studies using software-modified phones (SMP) reported, as we do, an underestimation, the magnitude of which differed however (Goedhart et al., 2015b; Inyang et al., 2009; Kiyohara et al., 2016). A study applying the same methods as the current study, among adults, found a significant but smaller underestimation of number of calls (GMR = 0.65), and a smaller non-significant overestimation of duration of calls (GMR = 1.11) (Goedhart et al., 2015a). The Interphone validation study, among adults, found that individuals on average slightly underestimated the number of calls (GMR = 0.92) while duration of calls was overestimated (GMR = 1.42) (Vrijheid et al., 2006a, Vrijheid et al., 2006b). One previous study compared estimated versus billed text messages, and observed - in line with our results - that the number of text messages was on average overestimated (Redmayne et al., 2012).

We observed differences in recall by country, age, maternal educational, and amount of reported phone use. Differences by country were not observed in the CEFALO validation study (2 countries) (Aydin et al., 2011a), but were seen in the Interphone validation study among adults (11 countries; (Vrijheid et al., 2006a, Vrijheid et al., 2006b)). In the current study, where, as in Interphone, the same protocol and software app were applied in each country, we cannot easily explain the different ratios between self-reported and recorded use (ranging from 0.31 to 0.96 for number of calls and from 0.56 to 3.61 for duration of calls) found between the countries, other than cultural differences in the way people recall their use. It might be important to take these differences into account in future studies.

In young people, differences in recall by age, with a higher ratio among younger ages, were also seen by (Kiyohara et al., 2016). The CEFALO validation study, however, found a higher ratio among the older age group (15–19 vs. 7–14 years) (Aydin et al., 2011a). The impact of maternal education level on recall has not been shown before.

Table 6
Self-reported hands-free device use compared over time (before, after 6 and 18 months).

	Before (0 months)					
	Headset		Speaker mode		Bluetooth	
	No, N (%)	Yes, N (%)	No, N (%)	Yes, N (%)	No, N (%)	Yes, N (%)
After 6 months						
No	**116 (86.6%)**	24 (46.2%)	**81 (74.3%)**	35 (43.8%)	**174 (98.3%)**	4 (77.8%)
Yes	18 (13.4%)	**28 (53.8%)**	28 (25.7%)	**45 (56.3%)**	3 (1.7%)	**2 (22.2%)**
Unknown	*4*		*1*		*4*	
After 18 months						
No	**112 (86.6%)**	26 (50.0%)	**71 (74.3%)**	29 (43.8%)	**172 (98.3%)**	6 (66.7%)
Yes	22 (16.4%)	**26 (50.0%)**	38 (34.9%)	**51 (63.8%)**	5 (1.7%)	**3 (33.3%)**
Unknown	*4*		*1*		*4*	

Included only individuals who had questionnaire data available for all three time points (N = 190).

Previous studies consistently observed a significant effect of the amount of phone use on recall, showing an increasing ratio with higher levels of *reported* phone use (Goedhart et al., 2015a; Kiyohara et al., 2016; Vrijheid et al., 2006a, 2006b) or a decreasing ratio with higher levels of *recorded* phone use (Aydin et al., 2011a; Redmayne et al., 2012). While these systematic recall errors could have important implications for the risk estimates in epidemiological studies exploring potential health risks from mobile phone use, simulations have shown that the large amount of random errors observed in these studies will have an even larger impact (Vrijheid et al., 2006a, 2006b).

The transfer of data via a smartphone has been increasing rapidly in the past years, especially with the rise of WiFi connections. It could therefore be important to include data transfer in future models estimating RF from mobile phone use. While our results showed that on average 72.5% of data was transferred via WiFi connection, this may well change with the rise of fast and affordable mobile data. RF exposure from data transfer depends on several factors, including the number of bytes transferred and the type and speed of the data connection. As these factors cannot be reported by participants, we asked the participants instead to estimate the time spent using the Internet on their smartphone. Time spent on the Internet, however, is a poor description of data sent since, for example email, surfing the Internet and Voice over IP connections imply very different amounts of data sent, and thus different RF exposures. It is therefore not surprising that we observed a poor correlation ($r = 0.39$) between self-reported time spent using the Internet and the recorded number of bytes transferred. Furthermore, the observation that a small amount of data transfer was also recorded for participants who reported no data use implies that people probably are unaware of some of their data use, likely due to applications (e.g., push/pull technology) that run in the background. The impact of the relatively poor estimation of data transfer in epidemiological studies on brain tumour risk from mobile phone might, however, not be as important as voice calls, as the source of exposure is farther away from the head than it is when using the phone for calling, hence exposure levels are much lower. Similarly, using hands-free devices may lower exposure levels by having the phone as source of exposure farther away from the head.

Laterality is an important factor for case control studies exploring brain tumour risk from mobile phones: the location of the mobile phone relative to the head (e.g.: left side vs right side) influences the region where most RF exposure is (Cardis et al., 2008; Wiart et al., 2011). The recorded data on laterality provided new and valuable insights in the patterns and validity of self-reported laterality. Two previous studies examining laterality among young people found some agreement (kappa($\kappa = 0.3$ (Inyang et al., 2010), $\kappa = 0.2$ (Kiyohara et al., 2016)) between self-reported and recorded laterality. They did not, however, report the actual percentages of time that the phone was held on the right and/or left side of the head, which can be used to adjust RF exposure estimations on either side of the head. We observed that the majority of participants consistently reported using the phone mainly on the right side of the head. Participants who reported right side use after 6 months actually used the phone for 71% (excluding call time away from the head) on the right side of the head. This percentage is lower than previously observed among adults (81%) (Goedhart et al., 2015a) and quite a bit lower than the 90% assumed in the Interphone study (Cardis et al., 2011). Self-reported left side users were more inconsistent, both in their report over time (i.e., only about half of the self-reported left side users at 6 months also reported left side use at 0 or 18 months) and compared to the recorded percentage of call time the phone was actually used on the left side of the head, which was only 54% on average. The study by (Kiyohara et al., 2016) also found a lower agreement of self-reported vs. recorded left side use compared to right side use. Participants who reported using the phone on both sides of the head were most inconsistent in their report over time, and the recorded laterality reflected somewhat more right (57%) than left side (43%) use of the phone. While we observed an inverse association between amount of phone use and the agreement between self-reported and recorded laterality, this was not observed by Kiyohara et al. (2016). Our results indicate that young people, compared to adults, tend to use their phone more frequently on both sides of the head, especially self-reported left and both side users. So far, epidemiological studies on brain tumour risk from RF accounted for laterality, in the way that a potential risk was mainly expected on the side of the head the phone was primarily held (ipsilateral exposure) (Cardis, 2010). Our observations, however, imply that accounting for laterality could be less informative when studying young people, as they are frequently exposed on both sides of the head. Certainly, the assumption of 90% ipsilateral use as used in the Interphone study would not hold for current studies among young adults.

The agreement between self-reported and actual hands-free usage among young people has not been studied before. In comparing the self-reported use of hands-free devices over time, we noticed that participants who reported not using hands-free devices, would still show a small amount of recorded hands-free device use (0.2–3.8% of total call time). A higher reported frequency (half of the call time or more) of wired headset or speaker mode use agreed with a higher recorded percentage of call time (17.2–17.1%) in which these devices were used compared to low frequent reporters (8.5–9.7%). Nonetheless, these percentages were much lower than assumed before in the Interphone study among adults (less than half of the call time, i.e., low frequent use: 0–25%, half or more of the call time, i.e., high frequent: 50–100%) (Cardis et al., 2011).

In contrast to several validation studies using operator records (Aydin et al., 2011a), the information recorded by the software app on number and frequency of voice calls was complete for the individuals included in the analyses; furthermore, the app also recorded information on laterality and hands-free usage. Although the period of recall in this study, at least for a subsample, was longer than in previous SMP-studies (Goedhart et al., 2015b; Inyang et al., 2009; Kiyohara et al., 2016), operator records often go even further back in time (Aydin et al., 2011a), which is useful in the context of case-control studies on brain tumour risk that have to account for a certain latency period. Our sample mainly consisted of healthy and motivated volunteers, making it less comparable to participants of a case-control study; the recall of cases may be worse as they may suffer from physical and/or psychological impairments. Nonetheless, a big strength of our study was the fact that nearly two-thirds of our participants downloaded the app on their own smartphone instead of using a study phone, thereby better reflecting normal phone use behaviour and less awareness of being observed (i.e., the so-called Hawthorne effect (McCambridge et al., 2014)).

In conclusion, we compared software-recorded mobile phone use with recall after 6 and 18 months. Agreement between reported and measured number of calls and duration of calls was moderate; systematic errors were observed, with number of calls being underestimated on average and duration of calls and number of text messages sent overestimated. We note that there was also substantial random error, which is likely to have a major effect on risk estimates. The recall errors observed in this study for voice calls, laterality and hands-free use will provide important input for the development of the RF exposure model based on self-reported mobile phone use within the MOBI-Kids case-control study.

Acknowledgements

The authors thank Thierry Sarrebourse and Emannuele Conil (WHIST Lab, France) for their technical support with the software application XMobiSense. Canada (Ottawa) received support from a peer reviewed university-industry partnerships grant from the Canadian Institutes of Health Research, with the Canadian Wireless Telecommunications Association (CWTA) as the industrial partner (http://www.crealradiation.com/index.php/en/mobi-kids-financial-sources). D. Krewski holds a Natural Sciences and Engineering Research Council of Canada Industrial Research Chair at the University of Ottawa, with CWTA as one of the industrial partners (http://www.nserc-crsng.gc.ca/Chairholders-TitulairesDeChaire/Chairholder-Titulaire_eng.asp?pid=316).

The Australian study center would like to thank Jin Ye Teo, Kristen Benke, and Rosa Schattner for data collection and follow-up of individuals. The Canadian study centre would like to thank Fatima Kazoun and Mackenzie Taylor Shaheen-Akins for data collection and recruitment. The French coordination would like to thank Stéphanie Bonnay, Brigitte Chazara, Véronique Dimper, Carine Jeunecout, Olivia Rick, and Xavier Schwall for their support in recruiting and interviewing volunteers. The Greek study center would like to thank Maria Karalexi, Evangelia Kontogeorgis and Elena Labropoulou for data collection and follow-up of individuals. The Italian study center would like to thank Laura Davico, Marco Gilardetti and Fulvio Lazzarato for data collection and follow-up of individuals. The Spanish coordinating center would like to thank Alex Albert and Albert Dalmau for their invaluable technical support. All study centers thank the volunteers for their participation in the study.

Declarations of interest

Canada (Ottawa) received financial support from the Canadian Wireless Telecommunications Association under the federal university-industry research partnerships programs noted below.

The rest of the authors declare no conflict of interest.

Grant sponsors

The research leading to these results has received funding from the French Agency for Food, Environmental and Occupational Health & Safety (ANSES) under grant agreement number No. 2011/1/216 the Mobi-Expo project, the Netherlands Organisation for Health Research and Development (ZonMw) under grant agreement numbers 85500022 and 85800001, the Korean IT R&D program of MSIP/IITP (B0138-16-1002, Study on the EMF exposure control in smart society), and the European Community's Seventh Framework Programme (FP7/2007–2013) under grant agreement number 22687 3- the MOBI-Kids project. The funding sources had no role in: the study design; the collection, analysis, and interpretation of data; the writing of the report; and the decision to submit the article for publication. Mention of trade names or commercial products does not constitute an endorsement or recommendation for use.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at http://dx.doi.org/10.1016/j.envres.2018.04.018.

References

Aydin, D., Feychting, M., Schüz, J., Andersen, T.V., Poulsen, A.H., Prochazka, M., Klæboe, L., Kuehni, C.E., Tynes, T., Röösli, M., 2011a. Predictors and overestimation of recalled mobile phone use among children and adolescents. Prog. Biophys. Mol. Biol. 107, 356–361. http://dx.doi.org/10.1016/j.pbiomolbio.2011.08.013.

Aydin, D., Feychting, M., Schüz, J., Andersen, T.V., Poulsen, A.H., Prochazka, M., Klæboe, L., Kuehni, C.E., Tynes, T., Röösli, M., 2011b. Impact of random and systematic recall errors and selection bias in case-control studies on mobile phone use and brain tumors in adolescents (CEFALO study). Bioelectromagnetics 32, 396–407. http://dx.doi.org/10.1002/bem.20651.

Aydin, D., Feychting, M., Schuz, J., Tynes, T., Andersen, T.V., Schmidt, L.S., Poulsen, A.H., Johansen, C., Prochazka, M., Lannering, B., Klaeboe, L., Eggen, T., Jenni, D., Grotzer, M., Von der Weid, N., Kuehni, C.E., Roosli, M., 2011c. Mobile phone use and brain tumors in children and adolescents: a multicenter case-control study. J. Natl. Cancer Inst. 103, 1264–1276. http://dx.doi.org/10.1093/jnci/djr244.

Cardis, E., 2010. Brain tumour risk in relation to mobile telephone use: results of the INTERPHONE international case-control study. Int. J. Epidemiol. 39, 675–694. http://dx.doi.org/10.1093/ije/dyq079.

Cardis, E., Deltour, I., Mann, S., Moissonnier, M., Taki, M., Varsier, N., Wake, K., Wiart, J., 2008. Distribution of RF energy emitted by mobile phones in anatomical structures of the brain. Phys. Med. Biol. 53, 2771–2783. http://dx.doi.org/10.1088/0031-9155/53/11/001.

Cardis, E., Varsier, N., Bowman, J.D., Deltour, I., Figuerola, J., Mann, S., Moissonnier, M., Taki, M., Vecchia, P., Villegas, R., Vrijheid, M., Wake, K., Wiart, J., 2011. Estimation of RF energy absorbed in the brain from mobile phones in the Interphone Study. Occup. Environ. Med. 68, 686–693. http://dx.doi.org/10.1136/oemed-2011-100065.

Goedhart, G., Kromhout, H., Wiart, J., Vermeulen, R., 2015a. Validating self-reported mobile phone use in adults using a newly developed smartphone application. Occup. Environ. Med. 72. http://dx.doi.org/10.1136/oemed-2015-102808.

Goedhart, G., Vrijheid, M., Wiart, J., Hours, M., Kromhout, H., Cardis, E., Eastman Langer, C., de Llobet Viladoms, P., Massardier-Pilonchery, A., Vermeulen, R., 2015b. Using software-modified smartphones to validate self-reported mobile phone use in young people: a pilot study. Bioelectromagnetics 36, 538–543. http://dx.doi.org/10.1002/bem.21931.

Inyang, I., Benke, G., McKenzie, R., Wolfe, R., Abramson, M.J., 2010. A new method to determine laterality of mobile telephone use in adolescents. Occup. Environ. Med. 67, 507–512. http://dx.doi.org/10.1136/oem.2009.049676.

Inyang, I., Benke, G., Morrissey, J., McKenzie, R., Abramson, M., 2009. How well do adolescents recall use of mobile telephones? Results of a validation study. BMC Med. Res. Methodol. 9, 36. http://dx.doi.org/10.1186/1471-2288-9-36.

Kheifets, L., 2005. The sensitivity of children to electromagnetic fields. Pediatrics 116, e303–e313. http://dx.doi.org/10.1542/peds.2004-2541.

Kiyohara, K., Wake, K., Watanabe, S., Arima, T., Sato, Y., Kojimahara, N., Taki, M., Yamaguchi, N., 2016. Recall accuracy of mobile phone calls among Japanese young people. J. Expo. Sci. Environ. Epidemiol. 26, 566–574. http://dx.doi.org/10.1038/jes.2015.13.

Langer, C.E., de Llobet, P., Dalmau, A., Wiart, J., Goedhart, G., Hours, M., Benke, G.P., Bouka, E., Bruchim, R., Choi, K.-H., Eng, A., Ha, M., Karalexi, M., Kiyohara, K., Kojimahara, N., Krewski, D., Kromhout, H., Lacour, B., Mannetje, A., Maule, M., Migliore, E., Mohipp, C., Momoli, F., Petridou, E., Radon, K., Remen, T., Sadetzki, S., Sim, M.R., Weinmann, T., Vermeulen, R., Cardis, E., Vrijheid, M., 2017. Patterns of cellular phone use among young people in 12 countries: implications for RF exposure. Environ. Int. 107, 65–74. http://dx.doi.org/10.1016/j.envint.2017.06.002.

McCambridge, J., Witton, J., Elbourne, D.R., 2014. Systematic review of the Hawthorne effect: new concepts are needed to study research participation effects. J. Clin. Epidemiol. 67, 267–277. http://dx.doi.org/10.1016/j.jclinepi.2013.08.015.

Mireku, M.O., Mueller, W., Fleming, C., Chang, I., Dumontheil, I., Thomas, M.S.C., Eeftens, M., Elliott, P., Röösli, M., Toledano, M.B., 2018. Total recall in the SCAMP cohort: validation of self-reported mobile phone use in the smartphone era. Environ. Res. 161, 1–8. http://dx.doi.org/10.1016/j.envres.2017.10.034.

Redmayne, M., Smith, E., Abramson, M.J., 2012. Patterns in wireless phone estimation data from a cross-sectional survey: what are the implications for epidemiology? BMJ Open 2, 1–8. http://dx.doi.org/10.1136/bmjopen-2012-000887.

Sadetzki, S., Langer, C.E., Bruchim, R., Kundi, M., Merletti, F., Vermeulen, R., Kromhout, H., Lee, A.-K., Maslanyj, M., Sim, M.R., Taki, M., Wiart, J., Armstrong, B., Milne, E., Benke, G., Schattner, R., Hutter, H.-P., Woehrer, A., Krewski, D., Mohipp, C., Momoli, F., Ritvo, P., Spinelli, J., Lacour, B., Delmas, D., Remen, T., Radon, K., Weinmann, T., Klostermann, S., Heinrich, S., Petridou, E., Bouka, E., Panagopoulou, P., Dikshit, R., Nagrani, R., Even-Nir, H., Chetrit, A., Maule, M., Migliore, E., Filippini, G., Miligi, L., Mattioli, S., Yamaguchi, N., Kojimahara, N., Ha, M., Choi, K.-H., Mannetje, A., Eng, T., Woodward, A., Carretero, A., Alguacil, G., Aragones, J., Suare-Varela, N., Goedhart, M.M., Schouten-van Meeteren, G., a A.Y.N, Reedijk, a.A.M.J., Cardis, E., 2014. The MOBI-Kids study protocol: challenges in Assessing childhood and adolescent exposure to electromagnetic fields from wireless telecommunication technologies and possible association with brain tumor risk. Front. Public Heal. 2, 124. http://dx.doi.org/10.3389/fpubh.2014.00124.

Schoeni, A., Roser, K., Roosli, M., 2015. Memory performance, wireless communication and exposure to radiofrequency electromagnetic fields: a prospective cohort study in adolescents. Environ. Int. 85, 343–351. http://dx.doi.org/10.1016/j.envint.2015.09.025.

Vrijheid, M., Cardis, E., Armstrong, B.K., Auvinen, a., Berg, G., Blaasaas, K.G., Brown, J., Carroll, M., Chetrit, a., Christensen, H.C., Deltour, I., Feychting, M., Giles, G.G., Hepworth, S.J., Hours, M., Iavarone, I., Johansen, C., Klaeboe, L., Kurttio, P., Lagorio, S., Lönn, S., McKinney, P. a., Montestrucq, L., Parslow, R.C., Richardson, L., Sadetzki, S., Salminen, T., Schüz, J., Tynes, T., Woodward, a., 2006a. Validation of short term recall of mobile phone use for the Interphone study. Occup. Environ. Med. 63, 237–243. http://dx.doi.org/10.1136/oem.2004.019281.

Vrijheid, M., Deltour, I., Krewski, D., Sanchez, M., Cardis, E., 2006b. The effects of recall errors and of selection bias in epidemiologic studies of mobile phone use and cancer risk. J. Expo. Sci. Environ. Epidemiol. 16, 371–384. http://dx.doi.org/10.1038/sj.jes.7500509.

Wiart, J., Hadjem, A., Varsier, N., Conil, E., 2011. Numerical dosimetry dedicated to children RF exposure. Prog. Biophys. Mol. Biol. 107, 421–427. http://dx.doi.org/10.1016/j.pbiomolbio.2011.10.002.