

ORIGINAL ARTICLE

Trends in cell phone use among children in the Danish national birth cohort at ages 7 and 11 years

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We prospectively examined trends in cell phone use among children in the Danish National Birth Cohort. Cell phone use was assessed at ages 7 and 11 years, and we examined use patterns by age, by year of birth, and in relation to specific individual characteristics. There was an increase in cell phone use from age 7 (37%) to 11 years (94%). There was a clear pattern of greater reported cell phone use among children at age 7 years with later birth year, but this trend disappeared at age 11. Girls and those who used phones at age 7 talked more often and for longer durations at age 11 years. Low socio-economic status and later year of birth were associated with voice calls at age 7 but not at age 11 years. At age 11 most used cell phones for texting and gaming more than for voice calls. Further, children who started using cell phones at age 7 years were more likely to be heavy cell phone voice users at age 11 years, making early use a marker for higher cumulative exposure regardless of year of birth. As cell phone technology continues to advance, new use patterns will continue to emerge, and exposure assessment research among children must reflect these trends.

Journal of Exposure Science and Environmental Epidemiology (2016) **26**, 606–612; doi:10.1038/jes.2016.17; published online 23 March 2016

Keywords: child exposure/health; EMF; epidemiology

INTRODUCTION

Cell phones were first marketed for commercial use some 30 years ago, and while initially cell phone use was uncommon, in the decades that followed cell phones evolved into an everyday necessity for much of the world's population. They are no longer simple devices for voice calls, and they affect most aspects of human life and culture. They have become a pervasive part of our society, and between 2000 and 2014, the number of active cell phone subscriptions increased from 700 million to nearly 7 billion, among a global population of 7.2 billion people.^{1,2} Advances in cell phone technology and availability have brought many advantages, including greater access to communication, information, and economic development and an astonishing array of resources to address almost any need or interest.

Despite the many benefits of this technology, there remain questions about its safety. There is public concern about harmful effects of cell phone use, especially for potentially vulnerable populations such as children. Besides the potential, but as-of-yet unestablished, effects of radiofrequency exposure, there is evidence for increased risks of serious injury and death due to cell phone use while driving, particularly among younger, less experienced drivers.^{3,4} Some research also suggests that cell phone use could lead to changes in behavior and cognition, with the potential to affect learning and academic performance among children and adolescents.^{5–7} The increasing popularity of this relatively new and rapidly changing technology, particularly among children and adolescents, makes it necessary to advance research in this field, and prospective cohort studies of exposure among children have been identified as a high-priority research

need by both the World Health Organization and the National Academy of Sciences.^{8,9}

It is generally not possible to assess detailed information about cell phone use in large epidemiologic studies due to cost and logistical challenges. Therefore, most large studies have assessed cell phone use in general. However, the exposure has changed with time and with changes in communication technology. Further, the level of exposure depends on a multitude of factors including specific cell phone use characteristics, such as the frequency and duration of calls, the location of the phone and antenna, and the use of hands-free devices. In addition, with changes in cell phone functionalities and modes of communication over time, the way that cell phones are used has evolved in recent years. They have gone from simple mobile telephones primarily used for verbal communication to multifunctional devices for verbal and text communication, work, and entertainment. Further, children born in the last 20 years have been exposed to this evolving cell phone technology from very early ages, and children's cell phone use characteristics, and thus, their overall exposure profile, may be different from adults. It is therefore important to understand how children use cell phones and how their use has changed over time.

Although many studies have examined patterns of cell phone use and access among adults,¹⁰ research among children and adolescents is limited. Most studies among younger users were based on cross-sectional data collected from different populations and using heterogeneous exposure assessment methods. Much of the existing data for children come from market research companies and the mobile phone industry itself. In general, the research suggests that cell phone use among children and

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Received 6 October 2015; accepted 31 January 2016; published online 23 March 2016

teenagers is quite common^{11–14} and that they are engaging in a variety of activities on cell phones besides voice calls.^{10,15–17} However, it is difficult to assess trends in cell phone use over time among these younger users with the existing cross-sectional data because the studies were carried out in different populations and cannot be compared directly. In order to fill the gap in knowledge about changes in cell phone use among children, we prospectively examined the patterns in cell phone use over time and across various characteristics among children in the Danish National Birth Cohort (DNBC). We compared cell phone use at age 7 years to use at age 11 years and examined the factors associated with these changes. We also examined specific cell phone use characteristics among 11-year old children.

METHODS

The DNBC enrolled 91,661 pregnant women in Denmark between 1996 and 2002. The women and children born from these pregnancies have been followed since enrollment with detailed data collection over the course of the children's lives. Information about the DNBC sample and data collection has been published previously.^{18,19}

Cell phone use in the DNBC has so far been assessed at two time points, when the child was 7 years old and again when the child was 11 years old. The age-7 wave of data collection began in April of 2005 and was completed in February of 2011. In all, 91,256 mothers were invited to participate in the age-7 wave of data collection. Of those invited, 59,975 (66%) completed the self-administered questionnaire, which focused on the child's health and development. In the age-7 questionnaire, mothers also reported their own cell phone use during pregnancy (prenatal exposure), and whether or not the child used a cell phone more than 1 h per week, < 1 h per week, or not at all (age-7 use). In responding to this question, mothers were asked to exclude any time the child spent on text messaging. This investigation includes 54,908 singleton-born children (e.g., not twins, triplets, etc) whose mothers participated in the age-7 wave of data collection.

When the children reached 11 years of age, a new wave of data collection began in July of 2010 and completed in August of 2014. All mothers and children who were still enrolled in the DNBC were invited to complete the age-11 questionnaires, regardless of their participation in the age-7 wave of data collection. A total of 90,986 mothers and their children were invited to participate in the age-11 wave, and 49,963 children (55%) and 47,721 mothers (52%) completed the questionnaires, where mothers with more than one child in the cohort are counted with multiplicity. The child's cell phone exposures at age 11 were reported independently by mothers and by the children. Mothers reported on whether or not the child used a cell phone more than 1 h per week, < 1 h per week, or not at all at age 11 years. Mothers were asked to exclude any time the child spent on text messaging, playing games, or similar activities. More detailed information about children's cell phone use was self-reported by the children themselves. Children reported their typical frequency and duration of speaking on a cell phone, use of hands-free devices, and the usual location of their phone when it was not in use. Children also ranked their frequency of engaging in different types of activities on their phones (i.e., "use phone for text messaging the most", "use phone for playing games 2nd-most", etc).

Statistical Analysis

We examined the trends in cell phone use among children over time and by year of birth to understand differences in use by age and to assess possible cohort effects. We also examined factors such as mother's age, mother's cell phone use, socio-economic status (SES), and child's sex and birth order as potential drivers of cell phone use. We considered cell phone use an attribute of children's behavior at the time of data collection rather than an event, and we therefore expressed our results in terms of relative prevalence (RP) rather than relative risk. We represented RP by prevalence ratios, which compare the proportion of individuals with an attribute in one group to the proportion with that attribute in a reference group. This is in contrast to relative risk, which compares the probability of an event between groups.

We performed regression analyses to estimate associations between specific individual characteristics and the child's cell phone use at ages 7 and 11 years reported as RP. We also estimated associations between cell phone use at age 7 years and frequency and duration of use at age 11 years. We further examined possible birth cohort effects on the relationship between use at age 7 years and frequent talking on cell phones at age

11 years. We chose the cut-point for frequent talking *a priori* as the 90th percentile of frequency of voice calls at age 11 years. We defined frequent talking as three or more voice calls per day. This represented the 86th percentile, which was as close to the *a priori* cutoff as possible given the distribution of the data. We first examined these possible birth cohort effects using regression analysis stratified by birth year. We then performed additional regression analyses that adjusted for birth year and the possible interaction between birth year and cell phone use at age 7 years to assess which factor is likely to be more predictive of frequent voice calls at age 11 years.

To understand how children typically use cell phones at age 11 years, we examined their self-reported rankings of text messaging, talking, playing games, and listening to music. We further estimated associations between sex, SES, and year of birth and the likelihood of ranking specific cell phone activities as first or second. We also examined associations between children's preferences for specific cell phone activities and their self-reported frequency and duration of cell phone voice calls.

Finally, because the children's cell phone use information was reported by both mothers and children, we assessed the agreement between mother's reports of their children's cell phone use at age 11 years and the children's self-reported usage.

Data analyses were performed in SAS software, version 9.2 (SAS Institute, Cary, NC, USA).

This research was approved by the DNBC, the Danish Data Protection Agency, regional science ethics committees in Denmark, and the Office of the Human Research Protection Program at the University of California, Los Angeles.

RESULTS

Data from the age-7 questionnaire were available for children born on or after 9 June 1997. The mean age of the children at the time of data collection is 7.2 years with a SD of 0.14 years. At the time of this analysis, we were unable to calculate children's exact ages when they completed the age-11 questionnaire, because information on individual interview dates was not available to us. However, only 4.9% of children who completed the age-11 questionnaire would have reached age 12 years or older at the start of the age-11 wave of data collection in July 2010 (data not shown).

Only 37% of 7-year-old children used a cell phone according to mothers' reports (Table 1), with < 1% using it more than 1 h per week. Use increased greatly by age 11 years, with more than 94% of children using a cell phone, and mothers reporting that nearly 12% used it more than 1 h per week.

According to mothers' reports, boys were less likely to use a cell phone at age 7 years than girls (RP: 0.84; 95% CI: 0.83, 0.86), but this difference in reported use by sex was not as large at age 11 years (RP: 0.95; 95% CI: 0.94, 0.95) (Table 1). Children from a higher SES background were less likely to use a cell phone at age 7 years, but by age 11 years, the relationship between SES and cell phone use was no longer apparent. Cell phone use at both age 7 and age 11 was associated with first-born status, younger maternal age, and maternal prenatal cell phone use but these associations were more strongly associated with use at age 7 than at age 11. There was a clear pattern of greater reported cell phone use among children at age 7 years with later birth year, but this trend disappeared at age 11.

At age 11, about two-thirds of children reported speaking on their phone between once per week and two times per day (Table 2). Most children reported typical phone calls lasting 1–4 min (61%) or < 1 min (25%). Boys were much less likely than girls to report speaking on a cell phone several times per day or for longer than 15 min at a time. About 5% of children kept their phones under their pillows or somewhere else in their beds at night, but most children (63%) kept their phones out of reach from their beds. Boys were less likely to keep their phones in or near their beds at night than girls. Although the majority of children (97%) reported typically holding their phones to their ears when they spoke on them, a small percentage reported using

Table 1. Associations between children's and mothers' characteristics and cell phone use at age 7 and age 11 based on mothers' reports.

	Child used cell phone at 7 years ^a		Child used cell phone at 11 years ^a	
	N (%)	RP (95% CI)	N (%)	RP (95% CI)
<i>Total used cell phone</i>	19,959 (36.5)	—	36,350 (94.3)	—
More than 1 h per week	431 (0.8)	—	4447 (11.5)	—
Less than 1 h per week	19,528 (35.8)	—	31,903 (82.8)	—
<i>Child's sex</i>				
Boy	9380 (33.5)	0.84 (0.83, 0.86)	17,566 (91.8)	0.95 (0.94, 0.95)
Girl ^b	10,579 (39.7)	1.00	18,784 (96.8)	1.00
<i>Socio-economic status</i>				
High	12,433 (34.4)	0.71 (0.68, 0.75)	24,453 (93.9)	1.00 (0.98, 1.01)
Medium	5726 (40.1)	0.83 (0.79, 0.88)	9035 (95.1)	1.01 (1.00, 1.03)
Low ^b	831 (48.2)	1.00	966 (94.1)	1.00
<i>Child's year of birth</i>				
2003	948 (45.8)	1.56 (1.47, 1.66)	1450 (94.1)	0.99 (0.97, 1.00)
2002	4397 (43.8)	1.49 (1.43, 1.56)	6286 (93.9)	0.99 (0.98, 0.99)
2001	4645 (40.3)	1.37 (1.31, 1.43)	7448 (94.0)	0.99 (0.98, 1.00)
2000	4401 (33.9)	1.15 (1.10, 1.21)	8560 (94.2)	0.99 (0.98, 1.00)
1999	3582 (31.9)	1.09 (1.04, 1.14)	7944 (94.6)	0.99 (0.98, 1.00)
1997–1998 ^b	1986 (29.4)	1.00	4662 (95.2)	1.00
<i>Child's birth order</i>				
Third-born or later	2574 (31.1)	0.80 (0.77, 0.83)	5244 (92.0)	0.96 (0.96, 0.97)
Second-born	6894 (35.7)	0.92 (0.90, 0.94)	12,416 (93.6)	0.98 (0.97, 0.99)
First-born ^b	9588 (38.8)	1.00	16,874 (95.5)	1.00
<i>Mother's age at birth of child</i>				
40 or older	417 (33.0)	0.63 (0.58, 0.69)	816 (92.9)	0.96 (0.95, 0.98)
35–39	2862 (33.0)	0.63 (0.61, 0.66)	5637 (93.0)	0.97 (0.96, 0.98)
30–34	7381 (33.8)	0.65 (0.63, 0.67)	14,577 (94.0)	0.98 (0.97, 0.98)
25–29	7460 (38.6)	0.74 (0.71, 0.77)	13,080 (94.9)	0.99 (0.98, 0.99)
Younger than 25 ^b	1839 (52.1)	1.00	2240 (96.3)	1.00
<i>Mother used cell phone while pregnant</i>				
Yes	10,542 (48.0)	1.72 (1.69, 1.76)	11,514 (96.0)	1.03 (1.03, 1.04)
No ^b	8437 (27.8)	1.00	16,213 (93.1)	1.00

Abbreviations: CI, confidence interval; RP, relative prevalence. Note: missing values not included. ^aAny cell phone use including < 1 h per week or more than 1 h per week as reported by mothers; does not include text messages, games, and so on. Reference is no use. ^bReference.

headphones or speakerphone, and this was slightly more common among boys than girls (RP: 1.13; 95% CI: 1.01, 1.27).

Both the self-reported frequency and duration of cell phone voice calls at age 11 years were higher among children who were already using a cell phone at age 7 years, even after adjustment for year of birth, sex, SES, birth order, mother's age, and maternal prenatal cell phone use (Table 3). Children who used a cell phone at age 7 years were more likely to report making three or more voice calls per day than children who did not use a cell phone at age 7 years. Figure 1 illustrates that this association remained for each year of birth. The association was strongest for children born in 2003 (RP: 1.72; 95% CI: 1.21–2.45). When we included year of birth in the fully adjusted model (instead of stratifying by year of birth), we found that cell phone use at age 7 years was a stronger predictor of frequent voice calls at age 11 years (RP: 1.48, 95% CI: 1.39–1.57) than was at year of birth (RP: 0.90, 95% CI: 0.88, 0.91). We did not detect evidence of effect measure modification by year of birth (interaction term RP: 1.00, 95% CI: 0.96, 1.04).

When asked about activities performed the most on cell phones, 42% of children at age 11 years reported using cell phones mostly to send text messages, whereas 22% played games, 16% talked to other people, and 12% listened to music most often on cell phones (Figure 2). When asked about the activity performed second most on cell phones, talking was

reported most frequently, followed by texting, listening to music, and playing games.

Boys were less likely than girls to report text messaging as the first- or second-most common activity for which they used a cell phone, but they were more likely than girls to report using cell phones for playing games (Table 4). Boys were also more likely to reporting talking to other people as their primary or secondary activity than girls. Text messaging and talking were both associated with higher social-occupational status, whereas playing games and listening to music were not. Children born later were less likely to report text messaging or listening to music as their primary or secondary activity, but they were much more likely to report playing games as their primary or secondary activity than children born earlier.

Children who ranked texting as their primary or secondary cell phone activity were somewhat more likely to report using their phone for five or more voice calls per day than children who ranked texting lower (RP: 1.17; 95% CI: 1.07, 1.30), but the duration of their calls tended to be shorter (Table 5). Children who reported playing games as their primary or secondary cell phone activity spoke on their cell phones less frequently and for shorter durations per call. Children who reported listening to music as their primary or secondary activity also reported less-frequent voice calls, but they tended to report longer call durations. These

Table 2. Children's cell phone use characteristics at age 11 years overall and by sex based on self-report.

	Total	Boys	Girls ^a	RP (95% CI)
<i>Frequency of voice calls</i>				
5 or more times per day	2121 (4.7)	837 (3.9)	1284 (5.4)	0.59 (0.55, 0.63)
3–4 Times per day	4132 (9.1)	1552 (7.2)	2580 (10.9)	0.67 (0.64, 0.69)
1–2 Times per day	10,901 (24.1)	4573 (21.2)	6328 (26.7)	0.85 (0.83, 0.86)
3–6 Times per day	10,013 (22.1)	4673 (21.7)	5340 (22.5)	0.87 (0.86, 0.89)
1–2 Times per week	9468 (20.9)	4761 (22.1)	4707 (19.9)	0.90 (0.88, 0.91)
2–3 Times per month	4894 (10.8)	2709 (12.6)	2185 (9.2)	0.90 (0.87, 0.93)
Less than once per month ^a	2651 (5.9)	1667 (7.7)	984 (4.2)	1.00
Never	1038 (2.3)	758 (3.5)	280 (1.2)	—
<i>Typical duration of voice calls</i>				
More than 15 min	410 (0.9)	114 (0.6)	296 (1.3)	0.29 (0.24, 0.36)
10–14 min	858 (1.9)	218 (1.1)	640 (2.7)	0.27 (0.24, 0.32)
5–9 min	4559 (10.3)	1426 (6.9)	3133 (13.4)	0.45 (0.43, 0.48)
1–4 min	27,141 (61.4)	12,545 (60.4)	14,596 (62.4)	0.87 (0.86, 0.89)
Less than 1 min ^a	11,211 (25.4)	6469 (31.1)	4742 (20.3)	1.00
<i>Usual phone position during calls</i>				
Use bluetooth	73 (0.2)	41 (0.2)	32 (0.1)	1.41 (0.89, 2.24)
Use headphones/speakerphone	1184 (2.6)	601 (2.8)	583 (2.5)	1.13 (1.01, 1.27)
Hold phone to ear ^a	43,950 (97.2)	20,884 (97.0)	23,066 (97.4)	1.00
<i>Location of phone at night</i>				
Under pillow or in bed	2055 (4.7)	686 (3.3)	1369 (6.0)	0.51 (0.47, 0.56)
Beside the bed	13,879 (31.9)	6022 (29.1)	7857 (34.4)	0.82 (0.80, 0.84)
Some place farther away ^a	27,638 (63.4)	14,025 (67.7)	13613 (59.6)	1.00

Abbreviations: CI, confidence interval; RP, relative prevalence. Note: missing values not included. Results shown as frequency counts (percentage of column).
^aReference.

Table 3. Association between cell phone use at age 7 years and self-reported frequency and duration of voice calls at age 11 years.

	Used cell phone at age 7 years		RP (95% CI)	RP (95% CI) ^a
	Yes	No ^b		
<i>Frequency of voice calls^c</i>				
5 or more times per day	733 (5.9)	816 (3.6)	1.85 (1.72, 1.99)	1.43 (1.34, 1.53)
3–4 Times per day	1425 (11.4)	1676 (7.4)	1.49 (1.43, 1.56)	1.36 (1.29, 1.42)
1–2 Times per day	3439 (27.6)	5032 (22.1)	1.17 (1.15, 1.19)	1.12 (1.10, 1.14)
3–6 Times per week	2878 (23.1)	4954 (21.8)	1.15 (1.13, 1.17)	1.11 (1.09, 1.14)
1–2 Times per week	2333 (18.7)	5146 (22.6)	1.10 (1.08, 1.12)	1.09 (1.07, 1.11)
2–3 Times per month	1060 (8.5)	2788 (12.3)	1.11 (1.06, 1.15)	1.10 (1.05, 1.15)
Less than once per month ^b	461 (3.7)	1640 (7.2)	1.00	1.00
<i>Typical duration of voice calls^c</i>				
More than 15 min	119 (1.0)	165 (0.8)	1.70 (1.35, 2.14)	1.60 (1.26, 2.04)
10–14 min	269 (2.2)	351 (1.6)	1.76 (1.51, 2.05)	1.58 (1.35, 1.86)
5–9 min	1480 (12.0)	1958 (8.9)	1.52 (1.44, 1.61)	1.36 (1.29, 1.45)
1–4 min	7841 (63.6)	13,292 (60.3)	1.10 (1.09, 1.12)	1.08 (1.07, 1.10)
Less than 1 min ^b	2620 (21.3)	6286 (28.5)	1.00	1.00

Abbreviations: CI, confidence interval; RP, relative prevalence. ^aAdjusted for year of birth, sex, SES, birth order, mother's age, and maternal prenatal cell phone use. ^bReference ^cExcludes children missing data on cell phone use at age 7 years.

children were more likely to report speaking on a cell phone for more than 15 min (RP: 1.39; 95% CI: 1.10, 1.77) than children who ranked listening to music lower.

There were 34,442 mother–child pairs in which both the mother and the child completed the age-11 cell phone questions. Among them, mothers' reports of their children's cell phone use at age 11 years agreed with the children's self-report in nearly 95% of pairs, with both individuals reporting that the child used a cell phone at age 11 in 93.4% of pairs, and both reporting that the child did not use a cell phone at age 11 in 1.3% of pairs. In 4.2% of mother–child pairs, children reported using a cell phone at age 11 years,

but mothers did not corroborate the child's report. In 1.1% of pairs, mothers reported that their children used a cell phone at age 11 years, but the children did not self-report use. Agreement analysis resulted in a prevalence-adjusted bias-adjusted kappa coefficient of 0.89 (data not shown).

DISCUSSION

Our findings show a clear pattern of increasing cell phone use from ages 7 to 11 years among children in the DNBC, and we demonstrate associations between children's cell phone use and

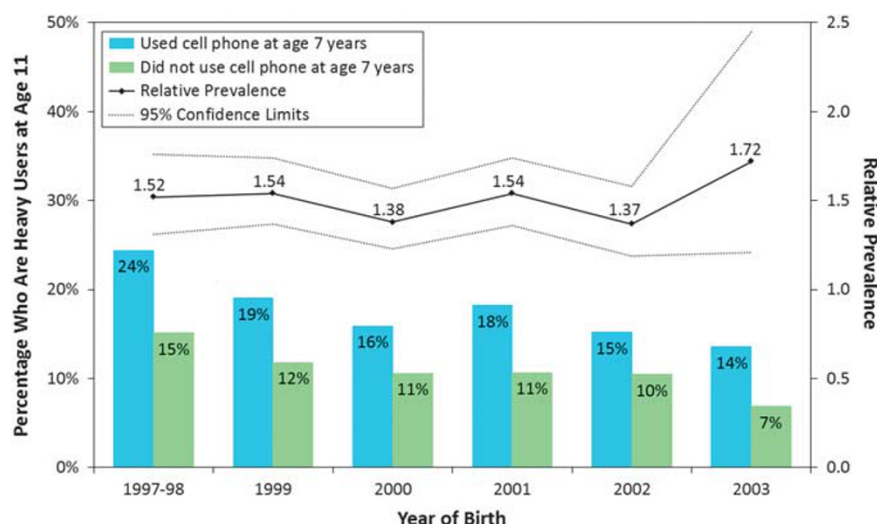


Figure 1. Heavy cell phone talking (three or more voice calls per day) at age 11 years based on child's self-report by cell phone use at age 7 years based on mother's report stratified by year of birth. Relative prevalence adjusted for sex, SES, birth order, mother's age, and maternal prenatal cell phone use.

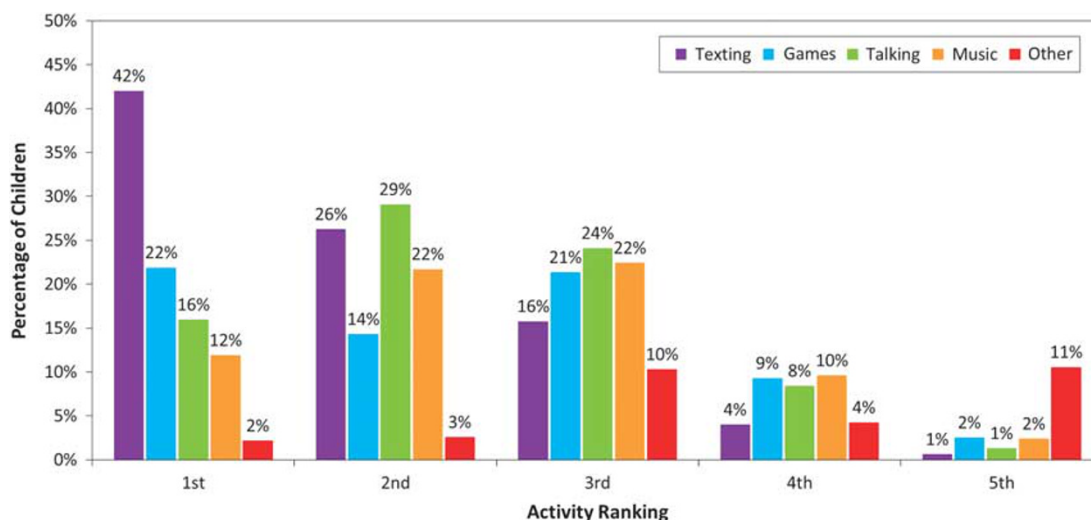


Figure 2. Ranking of cell phone activities self-reported by children at age 11 years. Missing values not shown.

various individual characteristics including year of birth, sex, SES, birth order, mother's age, and mother's use of cell phones during pregnancy. Our results shed new light on the ways in which children interact with cell phones, with 11-year olds reporting frequent text messaging and gaming on cell phones, more so than voice calls. Most remarkably, children who started using cell phones at age 7 years were more likely to be heavy cell phone talkers at age 11 years, and early use was a stronger predictor of frequent voice calls at age 11 years than was year of birth. These results suggest that cell phone use that begins at an early age may be a marker for heavier use later in childhood, as well as a marker for higher cumulative exposure.

Some characteristics showed sustained associations with mother's reports of their children's cell phone use at ages 7 and 11 years. Boys were less likely to use a cell phone than girls at both ages, although the association with gender was weaker at age 11 years. Likewise, children with no older siblings or younger mothers were more likely to use a cell phone at age 7 years and age 11 years. Children whose mothers used a cell phone during preg-

nancy were also more likely to use one at ages 7 and 11 years, but the association was particularly strong in relation to use at a younger age. Despite all of these factors, however, it is important to note that according to mothers reports nearly all children (94%) were using cell phones by age 11 years.

On the other hand, based on mother's reports some factors that were associated with cell phone use at age 7 years no longer appeared to have an impact on use at age 11 years. For example, children from a high SES background were much less likely to use a cell phone at age 7 years than those from a low SES background, but SES was unrelated to cell phone use at age 11 years. Similarly, there was a clear pattern of higher prevalence of use at age 7 years among children born more recently, but this association disappeared when examining use at age 11 years. These findings seem to suggest that SES and year of birth are important for driving use among younger children but may not be as relevant at older ages when cell phone use reaches nearly complete penetration. However, when we examined children's self-reported rankings of cell phone activities, we found that children from

Table 4. Ranking cell phone activities first or second by individual characteristics.

	Texting		Games		Talking		Music	
	1st or 2nd (%)	RP (95% CI) ^a	1st or 2nd (%)	RP (95% CI) ^a	1st or 2nd (%)	RP (95% CI) ^a	1st or 2nd (%)	RP (95% CI) ^a
Sex								
Boy (n = 23,227)	57.6	0.74 (0.73, 0.75)	41.7	1.35 (1.32, 1.38)	47.3	1.11 (1.08, 1.13)	34.1	1.03 (1.00, 1.06)
Girl ^b (n = 24,972)	78.1	1.00	30.9	1.00	42.3	1.00	33.1	1.00
Socio-economic status								
High (n = 32,860)	68.9	1.10 (1.06, 1.15)	36.4	0.97 (0.90, 1.05)	46.1	1.16 (1.08, 1.25)	32.3	0.87 (0.81, 0.94)
Medium (n = 11,582)	66.5	1.07 (1.02, 1.12)	35.6	0.95 (0.88, 1.03)	42.3	1.07 (0.99, 1.15)	37.1	1.00 (0.92, 1.08)
Low ^b (n = 1218)	62.4	1.00	37.4	1.00	39.7	1.00	37.1	1.00
Year of birth								
2003 (n = 1901)	55.4	0.71 (0.68, 0.74)	53.3	2.23 (2.10, 2.37)	39.2	0.84 (0.79, 0.89)	28.4	0.81 (0.75, 0.87)
2002 (n = 8406)	58.2	0.75 (0.73, 0.76)	52.0	2.18 (2.07, 2.29)	43.5	0.93 (0.90, 0.97)	26.8	0.76 (0.72, 0.80)
2001 (n = 9899)	65.3	0.84 (0.82, 0.85)	45.4	1.90 (1.81, 2.00)	46.6	1.00 (0.96, 1.03)	26.6	0.76 (0.72, 0.79)
2000 (n = 11,158)	69.3	0.89 (0.87, 0.90)	31.3	1.31 (1.24, 1.38)	46.2	0.99 (0.96, 1.02)	35.7	1.02 (0.97, 1.06)
1999 (n = 10,674)	74.2	0.95 (0.93, 0.97)	24.2	1.01 (0.96, 1.07)	43.5	0.93 (0.90, 0.96)	43.1	1.23 (1.18, 1.28)
1997–1998 ^b (n = 6161)	78.2	1.00	23.9	1.00	46.8	1.00	35.2	1.00

Abbreviations: CI, confidence interval; RP, relative prevalence. ^aReference is ranked 3rd, 4th, 5th, or not ranked. ^bReference.**Table 5.** Association between activity ranking at age 11 years and self-reported frequency and duration of voice calls at age 11 years.

	Ranked texting as 1st or 2nd activity		Ranked games as 1st or 2nd activity		Ranked music as 1st or 2nd activity	
	RP (95% CI)	RP (95% CI) ^a	RP (95% CI)	RP (95% CI) ^a	RP (95% CI)	RP (95% CI) ^a
Frequency of voice calls						
5 or more times per day	1.43 (1.32, 1.54)	1.17 (1.07, 1.30)	0.58 (0.54, 0.63)	0.70 (0.65, 0.76)	0.80 (0.74, 0.85)	0.83 (0.77, 0.90)
3–4 Times per day	1.29 (1.23, 1.36)	1.14 (1.07, 1.21)	0.66 (0.63, 0.69)	0.72 (0.68, 0.76)	0.80 (0.77, 0.83)	0.83 (0.79, 0.88)
1–2 Times per day	1.13 (1.10, 1.15)	1.07 (1.05, 1.10)	0.84 (0.82, 0.86)	0.87 (0.85, 0.89)	0.90 (0.88, 0.91)	0.91 (0.89, 0.93)
3–6 Times per week	1.12 (1.10, 1.15)	1.08 (1.05, 1.11)	0.86 (0.84, 0.88)	0.89 (0.87, 0.91)	0.92 (0.90, 0.93)	0.93 (0.91, 0.95)
1–2 Times per week	1.12 (1.09, 1.15)	1.10 (1.07, 1.13)	0.91 (0.89, 0.93)	0.92 (0.90, 0.95)	0.95 (0.93, 0.97)	0.96 (0.94, 0.98)
2–3 Times per month	1.13 (1.09, 1.18)	1.11 (1.06, 1.16)	0.91 (0.88, 0.94)	0.92 (0.89, 0.96)	0.96 (0.92, 0.99)	0.96 (0.93, 1.00)
Less than once per month ^b	1.00	1.00	1.00	1.00	1.00	1.00
Typical duration of voice calls						
More than 15 min	1.05 (0.85, 1.29)	0.70 (0.53, 0.92)	0.67 (0.54, 0.82)	0.81 (0.62, 1.05)	1.37 (1.13, 1.66)	1.39 (1.10, 1.77)
10–14 min	1.38 (1.18, 1.61)	1.00 (0.83, 1.22)	0.78 (0.68, 0.89)	0.98 (0.83, 1.16)	1.14 (1.00, 1.30)	1.14 (0.97, 1.34)
5–9 min	1.22 (1.15, 1.29)	1.02 (0.95, 1.09)	0.91 (0.86, 0.95)	0.96 (0.90, 1.02)	1.03 (0.97, 1.08)	1.04 (0.98, 1.10)
1–4 min	1.06 (1.04, 1.08)	1.03 (1.01, 1.05)	0.99 (0.97, 1.00)	0.99 (0.97, 1.01)	1.00 (0.98, 1.01)	1.01 (1.00, 1.03)
Less than 1 min ^b	1.00	1.00	1.00	1.00	1.00	1.00

Abbreviations: CI, confidence interval; RP, relative prevalence. ^aAdjusted for year of birth, sex, SES, birth order, mother's age, and maternal prenatal cell phone use. ^bReference.

higher SES backgrounds were more likely to rank texting and talking as their most frequent or second-most frequent cell phone activities. Children born more recently were less likely to rank texting as one of their primary or secondary activities than older children, but they were much more likely to use their phones for playing games.

There were differences in cell phone use between boys and girls, with boys being less likely to use cell phones for communication than girls. Boys were not only less likely to use a cell phone according to mothers' reports, but at age 11 years, they also self-reported lighter cell phone voice call usage than girls, both in terms of frequency and duration of calls. Although only a small percentage (5%) of children reported keeping their phone in bed with them at night, girls represented the majority of these children. Although only a small percentage of children

(< 3%) reported using bluetooth, headphones, or speakerphone when speaking on their phone, boys were more likely to report using some kind of hands-free technology than girls. Sixty-eight percent of children ranked text messaging as the activity they performed most or second-most on their phones, but this was also dominated by girls, while playing games was more likely to be ranked first or second by boys.

Greene *et al.*²⁰ reported that mothers who continued participation for at least 7 years in the DNBC tended to be somewhat older and more likely to be in the highest SES group compared with those who discontinued participation earlier. Maternal age and SES may also be related to cell phone use among children, particularly use at younger ages. As 34% of invited mothers did not participate in the age-7 wave of data collection, and 45% of invited children and 48% of invited mothers did not participate in

the age-11 wave of data collection, we cannot rule out the possibility of bias due to selection-related factors in our results. If loss to follow-up in our study was related to SES or maternal age, the actual prevalence of cell phone use at age 7 years may be higher than what we reported. We would expect loss to follow-up to have less impact on the observed prevalence of cell phone use at age 11 years because cell phone use appears to be nearly universal by this age, but it may have affected the results observed for children's self-reported cell phone use behaviors somewhat.

Our study is based on prospective data collection from a large and well-documented cohort of children and mothers that contributes unique and important knowledge about cell phone use characteristics and trends among children. One of the limitations of our study is that detailed self-reported information about children's cell phone use characteristics and activities was only collected at age 11 years. Therefore, direct comparisons of use between ages 7 and 11 years were performed using mothers' reports of their children's cell phone use in general only. Although it would have been ideal to have more information about specific use characteristics at age 7, we do not expect a large proportion of 7-year olds in the DNBC to have been engaging in heavy text messaging, gaming, or voice calls—due to both their young age and the lower penetrance of cell phone technology at the time. We expect mothers' reports of cell phone use in general to be accurate overall, as we found 95% agreement between mothers' reports of their children's use and children's self-reported use at age 11 years.

CONCLUSIONS

With the rapid growth of cell phone use and its increasing popularity among children, our results are in line with societal trends. Our prospective evaluation of cell phone use over time provides information to guide exposure assessment methods and analyses in future epidemiologic studies of cell phone use among children. In particular, our findings suggest that studies among children should consider cell phone use both prior to and during adolescence and include assessments of various cell phone activities besides voice calls, including text messaging and gaming. Although our study did not directly assess additional cell phone activities such as social media and internet usage, we also expect these activities to be popular among older children and adolescents. As cell phone technology continues to advance, new use patterns will continue to emerge.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

ACKNOWLEDGEMENTS

We thank the coordinator of data collection, Inge Kristine Meder, data analysts, Inge Eisensee and Lone Fredslund Møller, and the participating DNBC mothers and

children. The research leading to these results has received funding from the European Community's Seventh Framework Programme (FP7/2007-2013) under grant agreement no 603794—the GERONIMO project.

REFERENCES

- 1 International Telecommunication Union. Global mobile cellular subscriptions, total and per 100 inhabitants, 2000-2010 2011.
- 2 International Telecommunication Union. Key ICT indicators for developed and developing countries and the world (totals and penetration rates) 2015.
- 3 Llerena LE, Aronow KV, Macleod J, Bard M, Salzman S, Greene W et al. An evidence-based review: distracted driver. *The journal of trauma and acute care surgery* 2015; **78**: 147–152.
- 4 Ferdinand AO, Menachemi N, Blackburn JL, Sen B, Nelson L, Morrisey M. The impact of texting bans on motor vehicle crash-related hospitalizations. *Am J Public Health* 2015; **105**: 859–865.
- 5 Ophir E, Nass C, Wagner AD. Cognitive control in media multitaskers. *Proc Natl Acad Sci USA* 2009; **106**: 15583–15587.
- 6 Lepp A, Barkley JE, Karpinski AC. The relationship between cell phone use, academic performance, anxiety, and Satisfaction with Life in college students. *Comput Human Behav* 2014; **31**: 343–350.
- 7 Courage ML, Bakhtiar A, Fitzpatrick C, Kenny S, Brandeau K. Growing up multi-tasking: The costs and benefits for cognitive development. *Dev Rev* 2015; **35**: 5–41.
- 8 World Health Organization. WHO Research Agenda for Radiofrequency Fields. Geneva, Switzerland 2010.
- 9 Barnes FS, Gandhi OP, Hietanen M, Kheifets LI, Matthes R, McCormick DL et al. *Identification of Research Needs Relating to Potential Biological or Adverse Health Effects of Wireless Communication Devices*. The National Academies Press: Washington, DC, USA, 2008.
- 10 Mascheroni G, Ólafsson K. The mobile internet: access, use, opportunities and divides among European children. *New Media Soc Online* 2015; 1–23.
- 11 Inyang I, Benke G, Dimitriadis C, Simpson P, McKenzie R, Abramson M. Predictors of mobile telephone use and exposure analysis in Australian adolescents. *J Paediatr Child Health* 2010; **46**: 226–233.
- 12 Mezei G, Benyi M, Muller A. Mobile phone ownership and use among school children in three Hungarian cities. *Bioelectromagnetics* 2007; **28**: 309–315.
- 13 Van den Bulck J. Adolescent use of mobile phones for calling and for sending text messages after lights out: results from a prospective cohort study with a one-year follow-up. *Sleep* 2007; **30**: 1220–1223.
- 14 Thomas S, Heinrich S, Kuhnlein A, Radon K. The association between socio-economic status and exposure to mobile telecommunication networks in children and adolescents. *Bioelectromagnetics* 2010; **31**: 20–27.
- 15 Madden M, Lenhart A, Duggan M, Cortesi S, Gasser U. *Teens and Technology* 2013. Pew Research Center's Internet & American Life Project: Washington, DC, USA, 2013.
- 16 GSM Association, Mobile Society Research Institute. *Children's Use of Mobile Phones - An International Comparison* 2012. NTT DOCOMO Inc.: Japan, 2013.
- 17 Selian A. Mobile Phones and Youth: A Look at the US Student Market. International Telecommunication Union 2004.
- 18 Olsen J, Melbye M, Olsen SF, Sorensen TI, Aaby P, Andersen AM et al. The Danish National Birth Cohort—its background, structure and aim. *Scand J Public Health* 2001; **29**: 300–307.
- 19 Sudan M, Kheifets LI, Arah OA, Divan HA, Olsen J. Complexities of sibling analysis when exposures and outcomes change with time and birth order. *J Expo Sci Environ Epidemiol* 2014; **24**: 482–488.
- 20 Greene N, Greenland S, Olsen J, Nohr EA. Estimating bias from loss to follow-up in the Danish National Birth Cohort. *Epidemiology* 2011; **22**: 815–822.