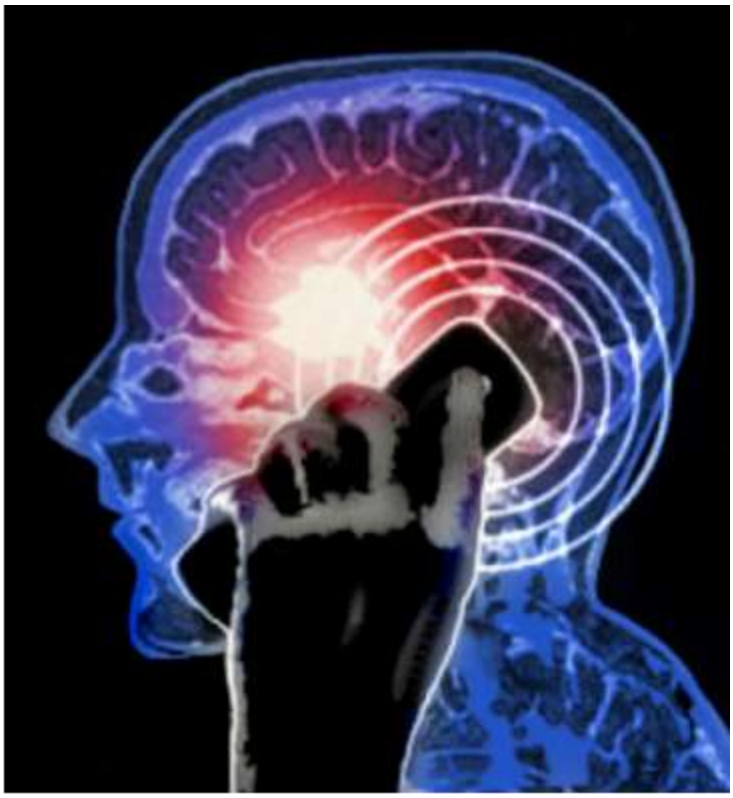
EPQ

CANCER IS A DISEASE CAUSED BY AN UNCONTROLLED DIVISION OF ABNORMAL CELLS IN A PART OF THE BODY WHICH CONTINUES TO AFFECT MILLIONS OF PEOPLE AROUND THE WORLD. IN THIS EPQ I LOOK TO INVESTIGATE INTO THE LINK BETWEEN A PERSON'S EXPOSURE TO MOBILE PHONES AND THE INCIDENCE OF BRAIN CANCER WITHIN THE UK. I QUESTION WHAT HAS ALREADY BEEN DONE TO DEAL WITH THIS ISSUE AND WHAT I WOULD DO IN THE FUTURE?



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Introduction

What am I investigating?

Within the UK, as well as on a more Global matter, Cancer is deemed to be a problem. The main reasons being that it both affects a high number of people and also accounts for a lot of deaths. Within the UK, it is estimated that roughly more than 1 in 3 people will at some point during their life be diagnosed with Cancer[1]. As well as this is was seen that there were 8.2 million deaths caused by cancer in the year 2012 alone.[2] Siegel et al. on behalf of the American cancer society also estimated that in the United stated alone during 2013, that overall there would be a grand some of 1,660,290 new cases of cancer with 580,350 deaths deriving from those cancers[3]. These statistics are backed up by both Cancer Research and the American Cancer society. Its severity is also shown by the American Cancer Society who published a journal which claimed that behind Heart disease, cancer accounted for the second most amounts of deaths within the US causing almost 1 of every

[1] (British Journal of Cancer et al., 2011, p. 1)
[2] (Bray, Ren, Masuyer, & Ferlay, 2013, p. 1)
[3] (Siegel, Naishadham, & Jemal, 2013, pp. 11–12)

4 deaths[4]. All of this contributes to why it is deemed to be such a problem in places such as the US and the UK.

Due to the array of differing opinions on what it is that actually leads to incidence of cancer there is much controversy over the causes. Hedenfalk et al.[5] made it clear that some cancers can be brought on genetically, i.e Breast Cancer, which is usually derived from mutations to the genes BRAC1 and BRAC2. Inheriting these genes can increase a person's chance of breast cancer by anything between 50 and 85 %. Another aspect which can contribute to the cause of cancer is environmental exposure. This being such things as tobacco and pesticides, however there is much controversy over these types of risk, as inevitability cigarette companies and so on find other evidence to prove otherwise, and therefore it does appear that most of the causes of cancer are actually very unclear. In a recent article Davis et al. actually categorized many of the controversial cancer causes such as "pesticide DDT, Gasoline engine exhaust, burning coal, dry cleaning chemicals and jet fuel"[6] as "Possible" carcinogen to humans, thus giving a level of severity to them. The figures and stats that I have presented here are extremely alarming and scary. However a topic of particular interest to me is that of Brain Cancer. And specifically the link between Brain Cancer and a person's exposure to Mobile phones can potentially lead to Incidence of Brain Cancer. This point of topic causes much controversy, as there are copious amounts of contradicting evidence arguing for the part it plays causing incidence and also how it does not cause incidence.
Mobile phones were described as a "possible" human carcinogen[7] by the World Health Organization, International Agency of Research On Cancer in 2011. However a case carried out by a range of corresponding experts on the topic in Sweden stated that is should be changed to a "probable human carcinogen"[8].The significance that its status has been changed from 'possible' to 'probable' is extremely significant, and thus emphasizes how we should be paying more attention to the possible link between Mobile Phones and Brain Cancer and how we can prevent incidence. However there are an array of opposing studies and surveys which conclude that there is no significant increased risk to a person's chances of getting cancer from mobile phones. These articles suggest that mobile phones are perhaps not a 'Probable human carcinogen', so I aim to look into the methodology behind such research and surveys and come up with a more conclusive answer on the base of my investigation.

Why I selected my title

As previously mentioned in my Project proposal, I have a very personal reason as to why I wish to explore this topic in greater depth. When I was at the age of 9, my sister died of a grade 4 glioma. My father took it upon himself to create a cancer charity and raise

[4] (American Cancer Society, 2013, p. 1)
[5] (Hedenfalk et al., 2001, p. 540)
[6] (Davis, Kesari, Soskolne, Miller, & Stein, 2013, p. 124)
[7] (Davis et al., 2013, p. 124)
[8] (Davis et al., 2013, p. 124)

awareness. Although I am connected on a very personal level to my project, I will keep my views completely unbiased and fair. The reason for selecting the link between Mobile Phones and the incidence of Brain Cancer is because it seems to be a topic with a very inconclusive outcome. Some are adamant that there is a link, whilst evidence does prove that there is no apparent link. I wish to research and get to some conclusive view of why people think there is an apparent link and whether anything has already or will be done about it.

How I am going to investigate this link?

My aim is to investigate the possible link between the incidence of Brain Cancer and exposure to the technology of mobile phones by analyzing the relationships between existing theories, assessing the methodology behind the experiments that we already know and perhaps what could be done in the future to prevent possible exposure. I aim to identify the main causes of worry regarding exposure to mobile phone technology and identify perhaps why it is believed that they will increase the incidence of cancer when one is exposed to them. From my investigation, I will examine my research and explore the ways in which I would recommend dealing with this problem.

Evaluation of sources

During this section I look to try and achieve a critical evaluation of the sources I have used when writing my project. This will involve me addressing the issues of credibility and reliability with the authors and websites in my writing. Obviously I attempted to use the most amount of reliable sources I could to ensure I strengthened the argument in my project. However because the link between Mobile Phones and the incidence of Brain Cancer is a much disputed and emotive argument, finding articles and journals which were written by credible sources without a underlying bias opinion was extremely difficult.

The majority of my journal articles included has come from libraries and specialist websites such as google scholar and jstor. This is because these journal articles produced by these websites are normally peer reviewed by corresponding experts and therefore they are much more reliable and credible. Where possible I have also tried to use specific experts in specific regions where I know that they have a reputation for being credible.
I have also included information from cancer charities. This being because they research and survey in much more depth compared to others. Therefore their information is reliable. However it is possible that these charities have some sort of vested interests as they could be looking for additional funding and donations to their charities. Therefore some statistics and figures might be manipulated. This is seen with an example of the ICR of the Institute of Cancer Research who supposedly who's funding and methods of research have been criticized is recent year.

One fundamental problem I had with the reliability of the information provided, not that they were not necessarily produced by credible and reliable authors but that technology has advanced in such a drastic way over just the last few years. By looking at peer reviewed articles dating back over 10-15 years. I felt that although there study was thorough and professional, technology has developed at such a rate since then and therefor I felt that these articles were perhaps out of date and were therefore no longer reliable sources. As these articles are unable to comment on whether the brain in affected in the long run by long term use of mobile phones. As well as this, technology has advanced and we know use different technology to when we did back then, when these studies were carried out. Frodin's article on "Radiotherapy in Sweden - a study or present use in relation to the literature and estimate of future trends" was exactly that. He presented good arguments, however it was published in 1996 and therefore I felt I could get use newer articles whose argument carried more weight and significance in their arguments.

With regards to the internet and the websites I used for my resources and information, it was difficult on occasions to find the information I needed without someone's own opinion attached to it. Due to the severity of the topic these opinions normally contained some sort of bias interpretation. With some internet websites containing articles which were written from a more emotive and subjective point of view rather than an objective one. Therefore including these in my project would only have made my argument weaker. There was an example of this on About.com which commented on a peer reviewed article, quoting what they thought was important. These short quotes did not give a true representation of the journal article and the results. Therefore was not fully informative and for that reason I left it out.

Another dilemma I was faced with when including sources was when I originally included information and quotations from 'Everything you need to know to help you beat cancer' and a cancer charity named 'CANCERactive'. However the author and director of the charity is my father, Chris Woollams. Knowing of my father's connection to this topic on a personal level, i felt that his writing was perhaps driven more by his emotions and by using his work I would relay some of his emotive type of writing and therefore thought better of using it and took it out of my project in order to sustain a more objective and unbiased style of writing.

Some of my sources were also not that credible such as Dr. John Mercola who is an osteopathic physician who specialises in alternative therapies and medicine. He is very opinionated in the way he writes and therefore by including his writing would not give my project any more weight. Henceforth I had to remove some quotes which I originally had of his as his opinions were not scientifically proven and therefore in a project like this could be perceived as insignificant. Therefore including his opinions and point of view might have weakened my argument.

Another factor I had to tackle was the copious amounts of research done on this topic. The amount of research into the potential link between the incidence of brain cancer and mobile phones I believe actually makes the reliability of other sources weaker. This topic is of high importance due to its severity and that I believe can lead to some studies' results

being manipulated. It is a highly controversial topic, and this is what I believe makes the studies which proof some sort of link much more valuable than those that do not prove a link. Therefore although some of my studies which are included do provide evidence of a link. This might have been done to increase the importance of their studies in comparison to others. Therefore although I have included some studies which state there is a small increased risk of gliomas and so on, some believe this could be for their own personal gain so that more people are interested by their journals and studies, therefore attracting more readers.

Cancer and Brain Cancer

What is Cancer?

I have used a medical dictionary here in my research to define the word 'Cancer'. This resource might not be the most reliable or credible however for a requirement of a definition I feel as though there can be no biased interpretations and therefore using any medical dictionary I am able to attain an equally informative answer compared to any other source. Therefore the description of cancer is "abnormal growth of cells which tend to proliferate in an uncontrolled way and, in some cases, to metastasize[9] (spread)".[10]

The following information is taken from Mary Anna Cutter et al. on behalf of the National Cancer Institute.[11] There is said to be four mutations to the development of Cancer, however this can vary. It is said that the number of mutations needed for a normal cell to evolve into a malignant cell is unknown yet it is estimated that it is fewer than 10. These cells which are altered grow and divides, this is known as hyperplasia. Then one of these cells will experience further division and begin to look different and abnormal. These abnormal cells can then form a mass of cells which is also known as a 'tumour'. This is called dysplasia. Another final mutation occurs against causing an increase in growth and a greater change in appearance.Tumors can both stay within the tissue in which it they originate from (in situ) or they can invade other tissues (invasive). Another characteristic of Cancer tumours is that they are either referred to as being 'benign' or 'malignant'. The National Cancer Institute[12] also states that 'Benign' refers to tumours that are only capable of growing where they originate from, and therefore cannot metastasize. 'Malignant' tumors are tumours that are able to metastasize and can increase in an uncontrolled fashion. Therefore The National Cancer Institute states that, "the term Cancer applies only to malignant tumours"

[9] Definition of 'Metastasize'. "To spread from one part of the body to another. When cancer cells metastasize and form secondary tumors, the cells in the metastatic tumor are like those in the original (primary) tumor." (National Cancer Institute, 2013a)
[10] (Medterms, 2013)
[11] (Mary Ann Cutter, Jenny Sigstedt, & Vickie Venne, 1999)
[12] (National Cancer Institute, 2005)

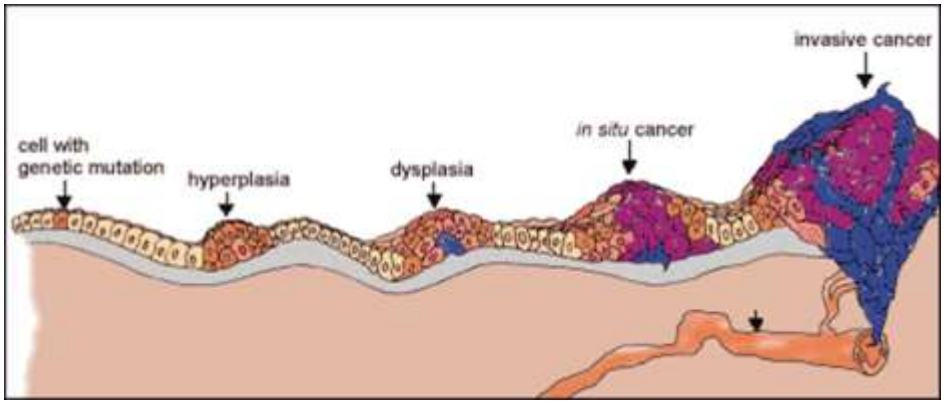


Figure 1 Shows the stages of tumor development[13].

What is Brain Cancer?

The main type of cancer I aim to look at throughout this project is Brain Cancer. Brain Cancer or a Brain Tumour, may be considered a primary cancer (this is where it originates in the brain), or a secondary cancer (where it originates elsewhere, for example in the colon and then spreads to other organs such as the liver and/or the brain)[14]. A Definition from the Mcmillan Cancer charity, this source is extremely reliable as they base their reputation on their information and knowledge and how they can make people aware. With supposedly over 130 different types and forms of brain cancer I couldn't possibly name and state the properties of all. Therefore I have decided to whittle down that 130 to the few most important ones which will probably come up somewhere else during my project or are common amongst cancer patients. Primary brain tumours originate from the cells that make up the brain and central nervous system. The most common types of adult brain tumours are gliomas and astrocytic tumours. They get their name because they are formed from the astrocytes and glial cells within the brain. Gliomas accumulate to equal 45% of all primary brain tumours. There are three main forms of glioma. It is said that "Astrocytomas account for roughly 75% of gliomas with other types of gliomas, for example oligodendroglioma and ependymoma making up the rest".[15] The first being Astrocytomas, this contributes for roughly 35% of all brain tumours and is the most common type of glioma. The next are oligodendrogliomas representing 3% of brain tumours. These can be highly dangerous as they can spread quickly if they are within the central nervous system. Lastly there are the ependymomas, which represent

[13] (Mary Ann Cutter et al., 1999)
[14] (Mcmillan Cancer Charity, 2012)
[15] (UCLA Health, 2013)

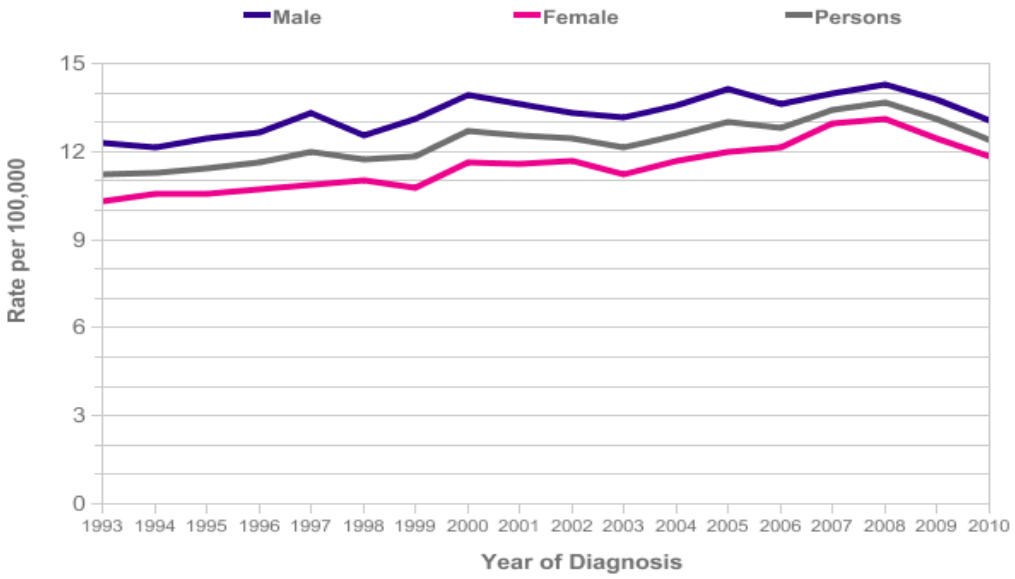
roughly 2% of all brain tumours. These can also be highly dangerous as there grading cannot always match the characteristics normally associated.[16]

Upon the diagnosis of a brain tumour, it will usually categorized by a 'grade'. The higher the grade the more likely the tumour is to metastasize and be malignant; therefore a grade is a clear indication of the severity of the cancer.

Astrocytoma are regarded as being one of the most common types of Brain Cancer. According to UCLA Health[17] they are assigned a grade from 1-4 to decided its severity. Grade 1 is called a Pilocytic Astrocytoma. These cancer cells look the same as normal cells and are benign (do not cause cancer). Grade 2 is where the cells first start to look 'abnormal' and the tumour will now begin to grow at a slow rate. This grade 2 tumour is called a low-grade Astrocytoma. At grade 3 the tumour is most likely malignant, the cell is now reproducing and has most definitely began to spread. A grade 3 tumour is called an Anaplastic Astrocytoma. Finally grade 4, a Glioblastoma multiforme is theoretically the most severe. A grade 4 tumours is where the tumour is almost definitely malignant, they include the same characteristics of all of the previous grades. However now the cells look extremely abnormal and it is possible for the tumours to form new blood vessels as this will aid them to continue to grow quickly.

Another type of brain tumour is an Acoustic Neuroma, which is mentioned later on in this project. They are benign and therefore not dangerous. However they are very difficult to recognize due to their rareness.

Research into the History and Statistics of Brain Cancer in the UK



[16] (Cancer Research UK, 2014)
[17] (UCLA Health, 2013)

Figure 2 - *"Brain, Other CNS and Intracranial Tumors, European Age-Standardised Incidence Rates, UK, 1993-2010"*[18]

Cancer Research here shows the rate of incidence in the UK since 1993 to 2010. What is obvious to see is that since 1993 we can see that there has been a gradual increase in incidence of Brain, Other CNS and Intracranial Tumors. There is a foreboding question as to why there is such a higher rate of Brain Tumors in men compared to women. The only conclusion that can be formed is that men are perhaps more vulnerable to these kinds of cancer, probably through certain lifestyle choices with incorporate the use of more men than women. These statistics are of significance. As it is obvious mortality and incidence is increasing slightly. With the advances that there have been in medicine and treatment within the last few years, the fact that mortality is increasing shows that these mortality rates are extremely significant

Brain Cancer Incidence and Mortality in England alone **(Figure 3)**[19]

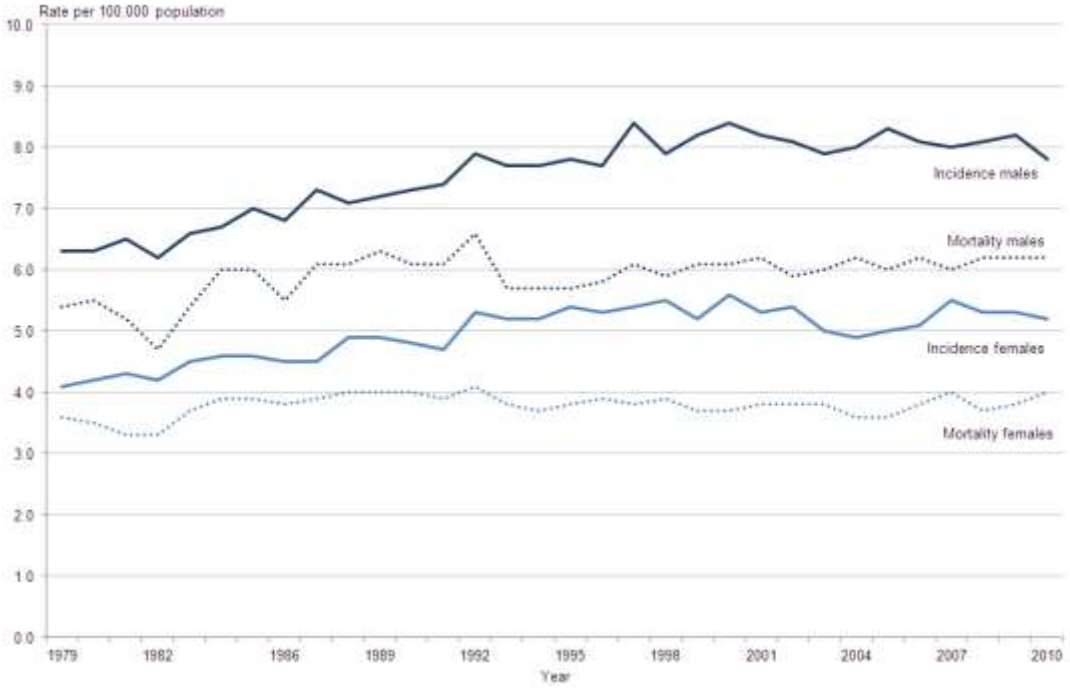


Figure 3 shows the incidence and mortality rates in England alone from roughly the 1980's to 2010. Yet again there is a significant difference between the incidence and death of Brain cancer associated between Males and Females. The reason figure 3 differs from figure 2 is that it is just showing brain cancer and not CNS and other intracranial tumours. With there being a significantly higher amount of males with incidence and morality. In conclusion we are able to see that incidence and mortality of Brain Cancer in

[18] (Cancer Research UK, 2013)
[19] (Office for National Statistics, 2013)

both the UK and England alone have increased within the last two decades. This also shows that incidence rates are increasing at a larger rate than the mortality rate, therefore we can deduce from this that there are more cases of brain cancer but less mortality. This could suggest that treatment has become much more effective over the years. The Office for National statistics have no incentive of money or any other sort of gain and therefore their surveys are extremely through and unbiased, thus giving us a true representation of the incidence rates.

Another significant survey carried out was in Canada. Where the Surveillance and Risk Assessment Division, Department of National Health and Welfare, Ottawa, Ont. decided to carry out a cancer experiment by analyzing the brain cancer patterns in Canada during the early 1990's. Their results are shown below in figure 4.

Results: The rates of death from brain cancer increased rapidly among Canadians aged 55 years or more from 1959 to 1988. In particular, age-adjusted death rates increased by 117%, 797% and 118% among men 65 to 74 years, 75 to 84 and 85 or more respectively. The corresponding increases among women were 138%, 535% and 400%. The incidence rates also increased substantially. The trends in incidence rates by tumour type indicated that the increase was more pronounced for glioblastomas. The incidence rates of cases detected histologically, radiologically and clinically all increased.

Figure 4 – *Increasing Brain Cancer rates in Canada*[20]

What we can therefore conclude from all this evidence is that Brain Cancer incidence and mortality has been rising for quite some time both within the UK and in Canada. The whole population of Canada was taken into account when working out figures and numbers and therefore draws conclusion that these percentages are in fact significant and of importance.

However it is highly difficult to pin point the causes of these increasing incidence rates. Instead it is possible that these increases in incidence came from increased use of newer technologies and the overall advance in technology and other environmental risk factors. For example Mobile Phones and radiofrequency emissions. It is extremely difficult to try and change these percentages into rates similar to that of Figure 2 and 3. And therefore is extremely difficult to draw some comparisons. However figures do correspond in that the mortality and incidence rates have also both increased.

[20] (Mao et al., 1991, p. 1583)

The link between Mobile Phone technology and the incidence of Brain Cancer

How does mobile phone technology affect the Brain?

Whether or not the technology associated with mobile phones actually causes incidence of Brain Cancer is a much disputed question. With vast amount of studies on the topic, it is obvious that there would be some studies which portray conflicting arguments, thus I aim to show as to why there is much controversy over whether or not mobile phones cause incidence of brain cancer. Whether or not Mobile phones increase the chance of incidence of Brain Cancer, is and will be under investigation for many years to come. At this moment it is said to be controversial. Timothy Moynihan a consultant in medical oncology who's achievement involve serving as the education chair for the Department of Oncology confirmed that "the many years' worth of studies on cell phones and cancer has yielded conflicting results. There is still a degree of ambiguity with the degree of risk posed by cell phones, if any at all"[21]. But equally the World health organization does state that "Significant concern has been raised about possible health effects from exposure to radiofrequency(R F) electromagnetic fields, especially after the rapid introduction of mobile telecommunications systems."[22] There is a supposedly growing concern from the World health organization The World health organization's aim is to "improve knowledge about attaining and maintaining good health".[23] Therefore it is safe to say that the information they provide is in no way manipulated. The concerns from radiofrequency fields are genuinely seen as being a growing concern in our society. But a 'growing concern' does not yet indicate that there is any real link.

When specifically identifying the problems associated with the technology of mobile phones, it appears that the main source of concern comes from the emissions of Radio waves. These electromagnetic radiation waves can be emitted by cell phones only when they are on, this is said to include when on 'stand by'.

One effect imposed on the brain by Mobile phones is the increase in temperature of the tissues in the brain when using a mobile phone. Scientists David Gultekin and Lothar Moeller were able to use a piece of machinery known as 'magnetic resonance imaging (MRI) technique'[24] which was able to see the effects on the brain by cell phones. Gultekin and Moeller were able to show that when the brain is subject to the same radio frequency signals that a cell phone gives off, the brain can 'heat up' and it appeared that

[21] (Moynihan, 2012)
[22] (Repacholi, 1997, p. 1565)
[23] ("WHO | Our aim," 2013)
[24] (Gultekin & Moeller, 2013, pp. 58–63)

the stronger the signal the more it 'heated up'. They used the same range to that of a typical mobile phone frequency and output, therefore these results were reliable and significant. With the change of output at 500mW resulting in a 1 degree increase. A charge of 1w resulted in a 3.5 degree increase and finally 2w resulting in a change of up to 5 degrees. These are substantial results that clearly indicate higher outputs and frequency affect the brain is greater way. And therefore presents the debate as to whether newer technology affects the brain more. Technology has progressed from generation to generation. Mobile phones have transformed from 2G to 3G and now to 4G. With the progression in generations of mobile phones, there is also a substantial increase in the frequency of these phones with newer technology resulting in a higher frequency. The newer the technology the higher there MHz. Therefore the underlying worrying question is to whether or no the phones with newer technology and higher frequency can affect the brain in a graver way. According to Gultekin and Moeller the brain will be affected more.

As well as this it is seen that regular use of mobile phones could break the safety barrier in the blood stream.[25] The brain contains endothelial cells which are the cells which form and make up the inner lining of the blood vessels within the brain and central nervous system. The use of mobile phones can see this endothelial cells begin to split, thus creating a gap. This gap can then lead to harmful toxins being able to access the brain through this gap, and therefore this is perceived as being dangerous as it could affect the neurons in the brain, the neurons are supported by the astrocytes cells and therefore damage to the neurons could potentially lead to Astrocytomas. However this is only a possibility and has not yet been proved. Therefore one cannot classify whether they do or do not cause cancer but it is advised that one should not talk for more than 50 minutes, as by that time there is a much higher rate of brain metabolism.

Another possible link between the brain and mobile phones derives from Heat Shock Proteins (HSP) also known as stress proteins. Heat shock proteins are able to repair damaged cells, when there is either a change in heat or the cell is under stress. It is believed that due to mobile phones increasing the temperature of the brain tissue and its cells, heat shock proteins are released. However the problem arises from the repeated use of mobile phones causes cellular stress to the cells in the brain which need to be constantly fixed by heat shock proteins. However the constant need for theses heat shock proteins can affect their normal pattern of the cells and tissues which can it is thought could perhaps cause incidence of cancer.[26]

What we are aware of is that the radiation emitted from these mobile phones is strong enough to infiltrate and penetrate our brains there is a cause of worry as it is now

[25] (Nittby et al., 2008, pp. 103–124)
[26] (Blank, 2012, p. 13)

believed that younger generations are beginning to spend longer amounts of time on the phone. In a study titled 'Exposure Limits: The underestimation of absorbed
Cell phone radiation, especially in children'. It was apparent that a child's brain is much more susceptible to radiation due to their brains being less developed and their skulls being much thinner than an adult[27]. Concluding that younger children and adolescents are affected much more. This is alarming for the future as a lot of studies carried out conclude that latency of longer than 10 years can lead to increased risk of cancer.

Figure 5 – Penetration of radiation on brain of an adult, a 10 year old and a 5 year old[28]

On recognizing that the radiation from mobile phones can penetrate the head, it is advised and also warned by various bodies and the government that you should keep your mobile phone at a distance. This can even be seen in the legal final print of any mobile phone manual, which offers advice and guidelines. Usually saying that you should keep your mobile phone at least 10 millimeters away from the body at all times. The question posed is that why the mobile phone companies themselves offer health guidelines if there was not a chance of health problems arising from the use of mobile phones.
What we can conclude from this Is that we can be sure that the technology used in mobile phones, does in some way inflict on the brain, all be it maybe not cancer causing.

As well as the evidence shown on the experiments including rats, there have been studies linking oxidative stress with the use of mobile phones by analysing a person's saliva. The results proved that "chatting for as little as eight hours a month causes higher oxidative

[27] (Gandhi et al., 2012)
[28] (SafeSpace, 2013)

stress".[29] What this indicates is that these cellular and genetic mutations which are said to cause the developments of tumours are caused by that oxidative stress. This appears to show the potential link of brain cancer incidence and mobile phone. However this might not be seen as being very significant due to the fact that the study was extremely small involving only a small confined number of users and non-users of mobile phones. Therefore with such a small contained group it is extremely unlikely that this study is at all reliable to represent the population. And therefore it was concluded that any significant evidence was difficult to take out of this study and that much larger and thorough investigations which concluded that there was not an increased risk of brain cancer incidence were still important and significant and take into account.[30]

Use of Mobile Phones and incidence of Brain Cancer

The possible link between the incidence of Brain Cancer and cell phones arose due to an increase in the incidence of Brain Cancer since the 1970's however, it was understood that cell phones weren't around in the 1970's and that increase was most likely due to an array of other factors[31]. This other factors could be linked to other lifestyle choices around that time, such as the level of exercise or the diet of a person. According to the International Telecommunication Union, the number of mobile phone subscriptions grew exponentially from 1.114 million in 1990 to 84.937 million in 2012[32]. With there being roughly 5 billion mobile phones users nowadays, hence we have increasing phone use and increased Brain Cancer incidence Yet their conclusive evidence was that their data suggested there was no link, yet they did say that further studies are needed to be carried out for longer induction periods[33].

[29] (Hamzany et al., 2013)
[30] (Hamzany et al., 2013)
[31] (Moynihan, 2012)
[32] (International Telecommunication Union, n.d.)
[33] (Muscat JE, Malkin MG, Thompson S, & et al, 2000, p. 3001)

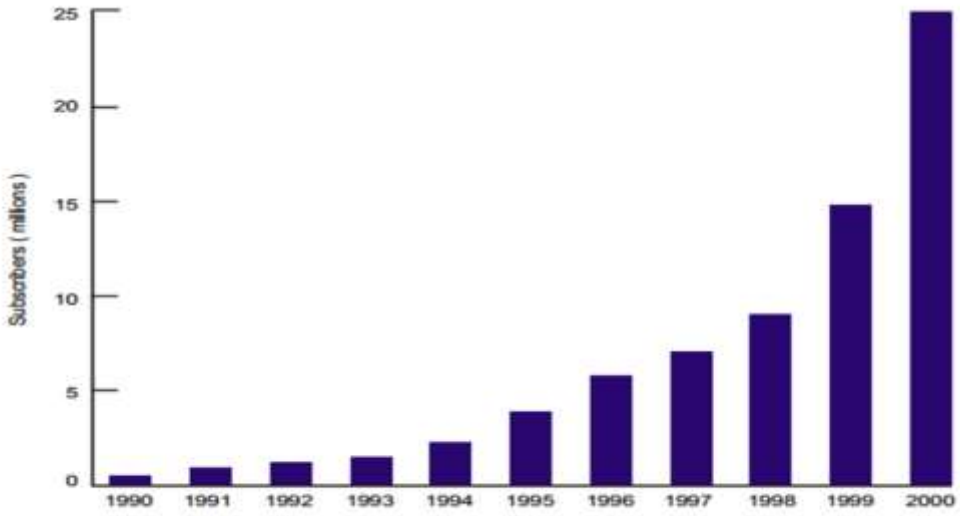


Figure 2.1 Growth in mobile phone subscribers in the UK between 1990 and 2000 (based on data from Federation of the Electronics Industry, FEI)

Figure 6 – '*Mobile Phones and Health (The Stewart Report)*'[34]

Figure 2.1 shows the increase in mobile phone subscribers from 1990 to 2000. We can see that Mobile phone subscribers within the UK between these time periods seemed to grow exponentially. The worry is if that this continues to grow at a similar rate and if there is a connection between mobile phones and cancer incidence, then what will happen in the future. With there currently now 82.7 million mobile subscriptions in the UK[35], we can see just the rate it has grown at during the last 20 years.

The problem associated with mobile phones is that they emit radio waves. It can be seen that both mobile phones and base stations (these being fixed installations what individual mobile phone are operated by) emit RF radiation. This radio waves emitted from mobile phones is a type of 'non-ionizing' radiation. This type of radiation is easily susceptible to the human head when the phone is held aside.[36] Hence is seen as being dangerous. The National Cancer Institute continued to state that the level of exposure one is vulnerable to depends on a few main factors. These main points consisted of "the technology of the mobile phone", the "distance between the mobile phones antenna and the user". With other contributions being the "extent and type of use" as well as the "distance the user is from the cell tower" Although there are precautions to reduce a person's vulnerability to their exposure Non-ionizing radiation supposedly does not cause cancer.[37] Exposure to ionizing radiation is known to increase the risk of cancer due to the amount of energy it has it is able to damage a person's DNA and cause mutations. But as of yet there is no

[34] (William Stewart, 2000, p. 12)
[35] (Mobile Operators Association, 2013)
[36] (National Cancer Institute, 2013)
[37] (National Cancer Institute, 2013b)

consistent evidence that non-ionizing radiation can increase cancer risk, as according to The World Health Organization, the energy released is not enough to damage a person's DNA with this being one of the main characteristics of cancer.[38] Therefore non-ionizing forms are seen as being safe from causing incidence of cancer.

The controversy is caused mainly by the fact that some studies show no significant link between mobile phones and the incidence of brain cancer, and others show that there is an increased risk of brain cancer for mobile phone users.

As most tests are inapplicable to humans due to risk factors, studies have been done on animals such as rats. In one study 3 different groups of rats were exposed to 2 hours' worth of Mobile phone electromagnetic fields, which differed in strengths and frequency. In this experiment which aimed to prove that there was damage to the nerve cells in a mammalian brain once there has been exposure to radiofrequency radiation. The results from The National Institute of Environmental Health Sciences found that there was damage to the neurons within the brain of these rats that had been exposed.[39] This was significant as for the first time it showed the neurons in the brain being affected by non-ionizing radiation. Since 2003 no other studies have really been able to conclusively find evidence similar to this. However this investigation was done on rats and therefore by attempting to see a similar pattern within humans, professors would have to test on humans which would obviously cause extreme complications. There have been other articles although which have used this study in their work and have tried to incorporate other ideas into it, such as Mae-wan Ho's study of 'Mobile Phones Damage the Brain'.[40]

[38] (World Health Organization, 2014)
[39] (The National Institute of Environmental Health Sciences (NIEHS) et al., 2003, p. 882)
[40] (Mae-Wan Ho, 2011)

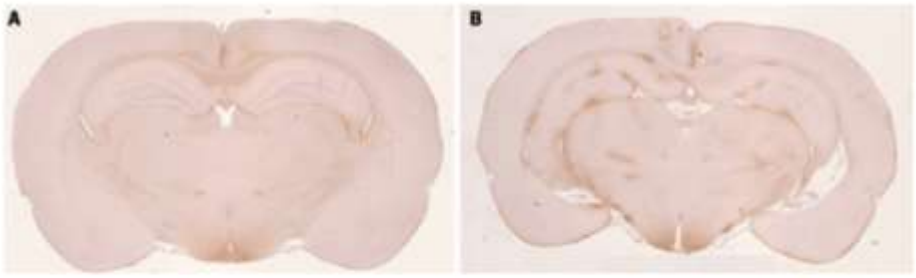


Figure 1. Cross-section of central parts of the brain of (*A*) an unexposed control rat and (*B*) an RF EMF-exposed rat, both stained for albumin, which appears brown. In (*A*), albumin is visible in the central inferior parts of the brain (the hypothalamus), which is a normal feature. In (*B*), albumin is visible in multiple small foci representing leakage from many vessels. Magnification, about ×3.

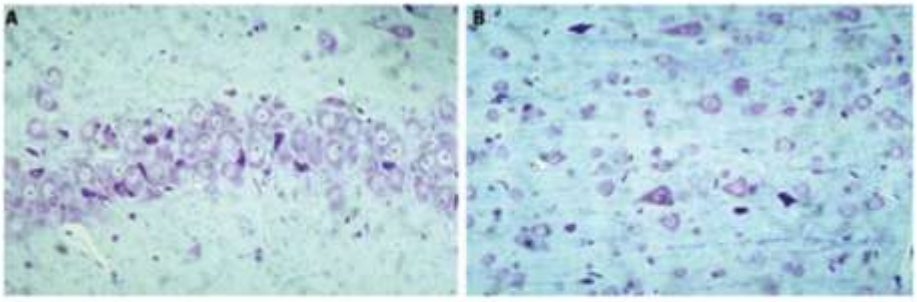


Figure 2. Photomicrograph of sections of brain from an RF EMF-exposed rat stained with cresyl violet. (*A*) Row of nerve cells in a section of the pyramidal cell band of the hippocampus; among the normal nerve cells (large cells) are interspersed black and shrunken nerve cells, so-called dark neurons. (*B*) The cortex, top left, of an RF EMF-exposed rat showing normal nerve cells (pale blue) intermingled with abnormal, black and shrunken "dark neurons" at all depths of the cortex, but least in the superficial upper layers. Magnification, ×160.

Presented here are Figures from *"Nerve Cell Damage in Mammalian Brain after Exposure to Microwaves from GSM Mobile Phone"*[41].

The result proved to be reasonably conclusive as for the first time damage to the neurons within the brain caused by to non-thermal radiation. Damaged neurons were located in various places within the brain; including the cortex, hippocampus and the basal ganglia.[42] Scientists have long been concerned about the possible harmful effects of regular mobile phone use. But no studies have produced clear results. Although not tested on humans, rats are said to have very similar nervous systems to that of ours. And therefore the results shown in are of significance and importance.

Due to the array of controversy and conflicting arguments I will present which have shown a potential link. As currently there is no consistent proof of any link, studies which reiterate this are unnecessary.

Firstly The Interphone study. The interphone study was and still is one of the largest pieces of work to date into the possible links between mobile phone use and cancer. This

[41] (The National Institute of Environmental Health Sciences (NIEHS) et al., 2003)
[42] (The National Institute of Environmental Health Sciences (NIEHS) et al., 2003)

studies evidence did suggest that there was an increased risk of incidence of glioma to those who spent a lot of time on the phone[43]. In some cases of the Interphone Study patients who had an increased risk of Brain Cancer were therefore described as being 'heavy users'. These people were much more subject and vulnerable to the increased risk of incidence of brain cancer. However the interpretation of their findings was perhaps inconsistent due to an array of problems involving selection bias. With their final concluding statement saying that it would require further investigation. However it is a good indication that there could be a link, with a significant number of countries being included in the study, 13 in total, including participation from "Australia, Canada, Denmark, Finland, France, Germany, Israel, Italy, Japan, New Zealand, Norway, Sweden and the UK". The strength in numbers was said to "maximize the statistical power" thus giving the evidence more weight for reasoning. The sheer size of the Interphone Study magnitudes the significance of their findings. With experts from an array of different countries and continents, they are able to collate their findings, resulting in reliable and credible results. With different countries, the use of mobile phones would vary, therefore by including these different countries and their date of mobile phones and usage; they give a very clear indication of the real problem at hand. A Study included in the Interphone Study Group' was, 'Cellular Phones, Cordless Phones, and the Risks of Glioma and Meningioma'. They concluded that with long term phone users, this being 10 years or more, their chances of glioma increased by almost 2 times.[44]

Korean Meta-Analysis (KORMA) Study Group. also carried out a study in which also concluded that there might be a possible link between mobile phones and the increased risk of brain cancer. This was shown by the evidence of increased risk in 13 studies when looking at the use of mobile phone use for over 10 years[45]. These 13 studies originally derive out of 23 studies including 37,916 participants, these figures can also be seen as arguing a strong case for whether or not mobile phones cause incidence of brain cancer. 13 out of 23 is over 50% and therefore quite a substantial figure. A study including long term mobile phone users proves that many of the studies which are done over 5 years or so might be conceivably unreliable as it is open to bias interpretations and human errors.

Another study titled 'Mobile Phone Use and the Risk of Acoustic Neuroma'[46], observed an increased risk of acoustic neuroma for mobile phone use of at least 10 years' duration. With an increased odds ratio of 4.8 for the left side of the brain and 3.8 for the right side of the brain. It was concluded that there was a strong link between the side of the head in which the mobile phone was used most and the larger the increased risk for brain cancer. With regards to the short term use of mobile phones and the risk of increased risk of brain cancer, results showed that there was no indication of a link.

[43] (INTERPHONE Study Group, 2010, p. 688)
[44] (Schüz et al., 2006, p. 515)
[45] (Myung et al., 2009, p. 5565)
[46] (Lönn, Ahlbom, Feychting, & Hall, 2004, p. 657)

All studies that have found an increase in the risk of incidence of acoustic neuromas bar from one concluded that in the short term there is no increase in risk. Lennart Hardell's 'Cellular and cordless telephones and the risk of brain tumors' study showed that there was an increased risk of acoustic neuroma's in the short term as well. The figures are shown below. However it was argued that this study came under much criticism due to only using 600 people in their experiment therefore any errors carried forward had a much larger effect on the statistics. As it was also looking at the side in which the tumour developed compared to what side a person used their mobile phone, it was believed that the patients could mislead the results by almost manipulating themselves into thinking that they used the phone on one side of the head more than the other.

	>1 year latency			>5 year latency			>10 year latency		
	Ca/Co	OR	CI	Ca/Co	OR	CI	Ca/Co	OR	CI
Analogue									
450 MHz	77/67	1.1	0.8–1.6	63/43	1.5	0.99–2.2	31/16	1.9	1.1–3.5
900 MHz	137/96	1.4	1.1–1.9	77/56	1.4	0.98–1.9	22/12	1.8	0.9–3.7
All	188/148	1.3	1.02–1.6	120/88	1.4	1.04–1.8	46/26	1.8	1.1–2.9
≤85 h	114/88	1.3	0.99–1.8	60/36	1.7	1.1–2.6	8/6	1.4	0.5–4.0
>85 h	96/82	1.2	0.9–1.6	72/64	1.2	0.8–1.7	39/21	1.9	1.1–3.2
Digital	224/228	1.0	0.8–1.2	33/36	0.9	0.6–1.5	–	–	–
≤55 h	165/156	1.0	0.8–1.3	8/13	0.6	0.3–1.5	–	–	–
>55 h	130/143	0.9	0.7–1.2	26/24	1.1	0.6–1.9	–	–	–
Cordless	238/242	1.0	0.8–1.2	102/77	1.3	0.99–1.8	6/3	2.0	0.5–8.0
≤183 h	136/162	0.9	0.7–1.1	35/27	1.3	0.8–2.2	0/1	–	–
>183 h	161/139	1.1	0.9–1.4	71/54	1.3	0.9–1.9	6/2	3.0	0.6–14.9

However an article titled 'Long-Term Mobile Phone Use and Brain Tumor Risk'[47] found conclusive evidence that there was no increased risk of glioma or meningioma's in either the short run or long run. The study included supposedly 3.9 million participants. And therefore was significantly thorough. However these participants all came from Sweden. It was also included in the INTERPHONE study and therefore was carried out in the same manner. However Cancer rates are different depending on different countries. Developing on evidence which has been contracted from one country does not give a true representative picture of the world. Therefore although in Sweden there was no increase in risk of brain cancer, it cannot be neglected that there could still be a link.

Interestingly a study carried out by the same authors titled 'Mobile Phone use and the risk of Acoustic Neuroma'[48], showed that there was an increase in risk of Acoustic neuroma. With significant findings when a person was subject to latency use of plus 10 years of a mobile phone. With the risk of incidence was also being much larger on the same side of the head that the mobile phone was used.

[47] (Lönn, Ahlbom, Hall, & Feychting, 2005, p. 529)
[48] (Lönn et al., 2004, p. 657)

Within all these studies it is shown that there is a potential link between mobile phones and Brain Cancer. However when using studies involving people who already have cancer it is very difficult to ensure that the results are not littered with errors. People who already have cancer might force the idea of which side they used the mobile phone more if there tumour is based on one side. Or they might comment on how they used their phones more than they actually did. This is supposedly physiological and patients will look to find some understanding in as to why they have brain cancer and therefore making up or slightly manipulating the truth gives them some sort of reasoning behind getting incidence of brain cancer. Therefore there needs to be leeway for human and bias error. Therefore it is difficult to find these studies extremely reliable as the professors have not been able to monitor them entirely since they first started using mobile phones.

Conclusion

All these studies and investigations would prove to make a significant argument for the fact that there is a 'probable' link between mobile phones and the incidence of Brain Cancer. There are also not any investigations to prove that there isn't any link at all. Many investigations do that there needs to be further research to provide significant evidence. Problems arise as it is very difficult to find anyone who will advertise or fund the research for looking into this possible link. As not only is there a lot of money in mobile phones but also in Cancer drugs and medicine, and although it appears sinful, it is a possibility that some people don't want this link to be exploited.

What is being done at the moment?

As shown in my project, there are copious amounts of different investigations and studies which have happened and are currently still underway in the attempt to prove a significant link between mobile phones and the incidence of Brain Cancer. These investigations fail to show a link of real significance as of yet, although there have been some small links associated.
Currently, without proof of such a link, many Government and other health bodies have set in place precautions and guidelines in which they hope that people will abide by. The NHS has set these set of guidelines to safeguard mobile phone users health.[49]

- Only make short calls on your mobile phone, and do not use it more than necessary.
- Children should only use mobile phones for essential purposes and keep all calls short.
- Find out the specific absorption rate (SAR) of a mobile phone before you buy it. This is how much radio wave energy is absorbed into the body from the mobile phone.

[49] (N. H. S. Choices, 2012)

SAR can vary between different types of phones. Mobile phone retailers have a responsibility to make this information available to you before you buy.

- Keep your mobile phone away from your body when it is in standby mode.
- Only use your phone when the reception is strong: this is often indicated by bars of energy on your phone screen. Weak reception causes the phone to use more energy to communicate with the base station.
- Use a mobile phone that has an external antenna. This keeps the radio waves as far away from your head as possible.

Due to the suggestion that these mobile phones could prove dangerous to health, these guidelines are put in places for precautionary measures. As well as these guidelines being set in place by the NHS and other reasonably large bodies, it is now evident that mobile phone companies are also including in their small print safety precautions. For example Vodafone, a very well-known and established mobile phone company. They advise on behalf of the World Health Organization "to keep their mobile calls short or text instead so that the mobile is not near their head for long periods of time" as well as this they advise to "Buy your son or daughter a hands-free set to distance the mobile from their head and body".[50]

They guidelines only offer advice and cannot make sure that people abide by these guidelines as it is in their hands to deal with. However considering that no significant link has been established yet they are good precautions to follow. Having the phone as far from the body is said to be safer and therefore the radiation cannot penetrate the body nearly as much as it would when next to it.

Another aspect which has been tackled by mobile phone companies is that they are attempting to make mobile phones safer. Over the year there has been the inclusion of speaker phones, Bluetooth and ear plugs. The main aim for these gadgets is to distinguish a larger gap between the mobile phone and the users head. As mentioned before, the head is susceptible to radiation from the phone which can cause health problems. With the generations increasing from 3G to 4G recently it is seen that mobile phone companies do not necessarily mind about the frequency in which these mobile phones emit. However this is the potential cause of worry, as the higher the frequency and energy the more radiation there is going to be. So the further the phone is away from the body the healthier it is seen to be.

As well as this currently there are undergoing projects still looking into the potential link between brain cancer and mobile phones. Two projects particularly taking my interest being COSMOS and Mobi-Kids.

[50] (Vodafone, 2013)

COSMOS which stands for 'Cohort Study of Mobile Phone Use and Health' is a study currently involving 290,000 participants all over the age of 18 years old, who will now be followed for between 20-30 years with reports being made and kept on the state of health. All participants agree to hand over access to their NHS and also give records of the mobile phone usage, these are then updated on a yearly routine. It involved the UK, Finland, Denmark, Netherlands and Sweden. As well as this France are looking to join the scheme having just received the funding. I believe this sort of study will advantageous at looking at the long-term effects of mobile phone use. This period of time for a study to undergo is extremely significant and substantial and hopefully will give us a clearer indication of whether there is a link between Mobile phones and Brain Cancer. However with people keeping track of their own records and only updating them once a year it will be difficult I believe for there to not to be some sort of error carried forward.[51]

Another scheme at the moment is 'Mobi-Kids'. Another study looking to investigate the link between Mobile phones and incidence of Brain Cancer. It will include a 1,000 young people between the ages of 10-24 who have already been diagnosed with brain cancer and a further 2,000 participants who are said to be healthy. They will then fill out questionnaires which will show the environmental exposures they left themselves vulnerable to and the risks associated with these. As well as this it will take into account family history age, gender and so on. The results are to be made public hopefully by the end of 2016 having run for roughly 5 years. This is a huge positive as with it only being 2 years away there is hope that there will be a chance of finding a link sooner rather than later. The only worry is if as mentioned before the effect of mobile phones has not been able to manifest yet as mobile phones have not been around long enough.[52]

What would I recommend as a result of what I have learnt?

With what I have learnt from this project is that so far there is an inconclusive answer as to whether there is a link between mobile phones and brain cancer and as to whether that link is of any significance. This is the same with any carcinogen. That finding the cause of cancer is known for being notoriously difficult, needing a lot of investigations and studies to prove a link. The problem I think being that mobile phones have not been around for a longer enough period for any assessment to carry any sort of significant weight as to whether they do cause incidence of cancer or impair health in some other way. From the majority of studies that I have researched an underlying theme is that the study has none been carried out for long enough to draw any firm conclusions from.

[51] (Imperial College London, 2013)
[52] (CREAL, 2013)

Therefore I would recommend from my findings that there needs to be experiments which go on for longer than 5-10 years. Preferably 30-40. These will be easier now considering that mobile phones have and will be around for many more years to come. The issue arising from this is that with the younger generations being able to access mobile phones with such ease. If there does prove to be a link later in life. Many of my generation and younger generations with have serious impairments to their health. Some of my studies showed that 'long term' mobile phone users were more susceptible to some types of brain tumors. I personally believe that mobile phones have become almost necessity and mandatory to have. As they now carry peoples calendars, their emails their pictures and so on. I suspect that not only will there been an increase in the amount of mobile phones bought and used, but I suspect that there will be an increase in the time people use their mobile phones for in the future as well. Henceforth if there is a link between cancer and mobile phones there could be a sudden dramatic increase in the rate of incidence of brain cancer within the years to come.

With regards to testing and experiments lasting for 30-40 years there is little that can be done about this, as time could be a key factor of how incidence of cancer could be caused.

The main cause of worry I believe is similar to that of cigarettes. With cigarettes there was a massive time lag between when people first start smoking ad finding that there was a link of increased cancer risk. I believe personally that this could be the same a as mobile phones. As well as this smoking one cigarette won't cause incidence of cancer, like using your mobile phone once wouldn't cause incidence of cancer once. However with younger generation being able to get mobile phones the use of those mobile phones will increase. It is seen that laws are implemented to prevent tobacco being sold to under 18's, I believe that a similar law should be enforced with Mobile phones if there is any sort of concern by the government over whether or not they are cancer causing. By looking at my research I believe it is acceptable to believe that mobile phones are a probable human carcinogenic.

For me I did this study to find personal answers and to get some sort of understanding about brain cancer. People shouldn't disregard the science; the studies I have presented do show that it is highly plausible for there to be a link between brain cancers and mobile phones. The only real advice I could give is to be cautious, parents should pay more attention to the amount of time their children spend on the phone as they are more unaware of the health effects. When I am a father my children won't be getting phones until the age of 16 in light of my research as I wouldn't possibly want to jeopardize their health when they are at such a vulnerable age. However by that time I would have hoped that there will be a conclusive answer as to whether or not there is a link.

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