

## RESEARCH

## CHRISTMAS 2014: MEDIA STUDIES

# Transmissibility of the Ice Bucket Challenge among globally influential celebrities: retrospective cohort study



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## Abstract

**Objectives** To estimate the transmissibility of the Ice Bucket Challenge among globally influential celebrities and to identify associated risk factors.

**Design** Retrospective cohort study.

**Setting** Social media (YouTube, Facebook, Twitter, Instagram).

**Participants** David Beckham, Cristiano Ronaldo, Benedict Cumberbatch, Stephen Hawking, Mark Zuckerberg, Oprah Winfrey, Homer Simpson, and Kermit the Frog were defined as index cases. We included contacts up to the fifth generation seeded from each index case and enrolled a total of 99 participants into the cohort.

**Main outcome measures** Basic reproduction number  $R_0$ , serial interval of accepting the challenge, and odds ratios of associated risk factors based on fully observed nomination chains;  $R_0$  is a measure of transmissibility and is defined as the number of secondary cases generated by a single index in a fully susceptible population. Serial interval is the duration between onset of a primary case and onset of its secondary cases.

**Results** Based on the empirical data and assuming a branching process we estimated a mean  $R_0$  of 1.43 (95% confidence interval 1.23 to 1.65) and a mean serial interval for accepting the challenge of 2.1 days (median 1 day). Higher log (base 10) net worth of the participants was positively associated with transmission (odds ratio 1.63, 95% confidence interval 1.06 to 2.50), adjusting for age and sex.

**Conclusions** The Ice Bucket Challenge was moderately transmissible among a group of globally influential celebrities, in the range of the pandemic A/H1N1 2009 influenza. The challenge was more likely to be spread by richer celebrities, perhaps in part reflecting greater social influence.

## Introduction

The Ice Bucket Challenge, a campaign to raise awareness and support for people with amyotrophic lateral sclerosis,<sup>1</sup> is widely recognised to have gone socially viral. Although there are variations to the trial, participants typically complete the challenge (they are doused in ice water or make a donation) and nominate three others to undertake it.<sup>2</sup> As of 1 September 2014, more than 17 million videos related to the Ice Bucket Challenge were shared on Facebook alone, and these were viewed more than 10 billion times by more than 440 million people.<sup>3</sup> Socially viral phenomena include videos that are made popular by sharing on the internet, and a video is said to have gone viral if it spreads rapidly as a result of frequent sharing.<sup>4,5</sup> However, the infectious disease modelling framework has seldom been used to quantify the transmissibility of such socially viral phenomena.<sup>6</sup> The most commonly used metric of transmissibility is the basic reproduction number ( $R_0$ ), defined as the number of secondary cases generated by a single index in a fully susceptible population.<sup>7</sup> The value of  $R_0$  is a major determinant of the size of an epidemic, and an infection can only be self sustaining if  $R_0$  is greater than 1. The  $R_0$  also provides a measure of the effort required to control the epidemic.<sup>7,8</sup> We estimated the transmissibility of the Ice Bucket Challenge among globally influential celebrities and identified the associated risk factors.

## Methods

### Participants

We considered globally influential celebrities who had undertaken the Ice Bucket Challenge to be eligible for inclusion.

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Extra material supplied by the author (see <http://www.bmj.com/content/349/bmj.g7185?tab=related#datasupp>)

Tree structure showing nominations associated with Cristiano Ronaldo  
Tree structure showing nominations associated with Oprah Winfrey

Global influence was defined by the criteria: listed in *TIME 100: The Most Influential People in the World*<sup>9</sup> or *TIME: Great People of the 20th Century*,<sup>10</sup> or having at least five million view counts for the Ice Bucket Challenge on YouTube. Among the small pool of potentially eligible participants we arbitrarily chose David Beckham, Cristiano Ronaldo, Benedict Cumberbatch, Stephen Hawking, Mark Zuckerberg, Oprah Winfrey, Homer Simpson, and Kermit the Frog as index cases (table 1). We also included successful nominations up to the fifth generation seeded from each index case.

## Data collection

We completed a marathon viewing of 145 Ice Bucket Challenges up to 13 September 2014. For each case we recorded the age, sex, occupation, net worth, popularity (proxied by number of likes on Facebook and number of Twitter followers), number of successful nominations, and total number of nominations. We obtained personal details of the celebrities from Wikipedia and specialised websites, although the validity of such information cannot be reliably ascertained.<sup>11</sup> Wikipedia has been used in previous studies<sup>12 13</sup> and its comparative accuracy has been reported.<sup>14</sup> From verified accounts we obtained the number of Facebook likes and Twitter followers. Where these were not available, we used the unofficial accounts with the most likes or followers. We excluded unofficial accounts with fewer than 1000 likes or followers.

We traced contacts through Google, YouTube, Facebook, Twitter, and Instagram. Online written or video responses by the nominated contacts were used to determine completion of the challenge. If we found no evidence for a response to the challenge on social media, it was assumed that the contact had declined. We included all successful contacts. Two of the authors (MYN, BHC) independently collected the data. After the fifth generation seeded from each index case they stopped data collection owing to investigator fatigue. We did not seek previous consent from participants as they presumably participated in the Ice Bucket Challenge without coercion, albeit with varying degrees of peer and social pressure.

## Statistical analysis

We used fully observed nomination chains to estimate the  $R_0$ , a measure of transmissibility, for a celebrities based cohort, up to the fifth generation seeded from each index case (the first generation).  $R_0$  was estimated as the product of the mean number of nominations ( $n$ ) and the probability of successful nomination ( $p$ ), assuming a branching process in which each participant of the Ice Bucket Challenge generates a random number of next generation participants. To account for the fact that the challenge had already taken off in early August 2014,<sup>15</sup> we excluded nominees in the calculation of  $p$  who had previously completed the challenge (that is, were “immune” from future participation) but included them in the calculation of  $n$  so that the estimated  $R_0$  would reflect the transmissibility in a fully “susceptible” population. We obtained 95% confidence intervals of the  $R_0$  estimate by bootstrap with 1000 replications. Mean serial interval was calculated by assuming at least a half day delay in accepting the challenge, based on all nominator-nominee pairs in our dataset. We used multivariable ordinal logistic regression to examine the association between number of successful nominations and personal factors (age, sex, occupation, and net worth) or popularity (number of likes on Facebook and number of followers on Twitter). To handle missing data we carried out sensitivity analysis with multiple imputation. All analyses were done using R version 3.0.2 and SAS university edition, 2014.

## Results

Eight index cases complied with the inclusion criteria. In total we included 91 nominees up to the fifth generation seeded from each index case, and a total of 99 participants were enrolled into the cohort. Overall, 24.2% of participants had zero successful nominations, 32.3% had one, 26.3% had two, and 17.2% had three. Twelve (4.9%) out of the 247 nominations had already participated in the Ice Bucket Challenge and were therefore “immune” from future participation. Among those observed were a Nobel laureate, a university vice chancellor, “heart throbs”, and Muppets (both the actors and the puppets). Among the index cases, Mark Zuckerberg’s nomination chain produced the most successful number of contacts (total of 41) up to the fifth generation (figure 1). No serious adverse events arising from the Ice Bucket Challenge act were observed in this series, but adverse events have been reported elsewhere,<sup>16</sup> including falls, head injuries, a temporomandibular joint dislocation, cuts, and at least one fatality. We estimated the measure of transmissibility,  $R_0$ , to be 1.43 (95% confidence interval 1.23 to 1.65) and a mean serial interval of accepting the challenge of 2.1 days (median 1 day). We excluded Homer Simpson and Kermit the Frog in the regression models because of difficulty in ascertaining their personal characteristics. Participants with a higher log (base 10) net worth were more likely to spread the Ice Bucket challenge (odds ratio 1.63, 95% confidence interval 1.06 to 2.50), adjusted for age and sex. One unit change on a log (base 10) scale is equivalent to a 10-fold change in net worth. We tested the proportional odds assumption for the regression model and found no indication of violation. Age, sex, occupation, number of Facebook likes, or number of Twitter followers were not associated with transmissibility (table 2). Data were missing for 24.0% of net worth, 15.6% of Facebook likes, and 13.5% of Twitter followers. Sensitivity analysis by multiple imputation yielded similar results (not shown).

## Discussion

The Ice Bucket Challenge—a campaign to raise awareness and support for people with amyotrophic lateral sclerosis by dousing oneself with a bucket of iced water or giving a donation—was moderately transmissible among a group of globally influential celebrities. The celebrities took a mean 2.1 days (median 1 day) to accept the challenge (the serial interval). Our finding of an  $R_0$  value greater than unity (1.43), indicating sustained spread, in a celebrities based cohort is consistent with observations reported in the press. Indeed this social viral pandemic shares a similar  $R_0$  with pandemic A/H1N1 2009 influenza, or the high end of the Middle East respiratory coronavirus since 2012 (table 3). Nine out of the 99 participants (9.1%) completed the challenge but did not nominate anyone, analogous to self isolation. We included these participants in our analyses and assumed all losses to follow-up to have declined the challenge. As with other microbial pathogens, transmissibility of the Ice Bucket Challenge may also exhibit seasonal variation,<sup>17</sup> where it might be anticipated that the  $R_0$  value would decrease during winter.

Possible factors accounting for the speed and extent of the Ice Bucket Challenge pandemic may include the online social media mode of transmission and the short serial interval for taking up the challenge (table 3). Despite a lower  $R_0$  than for measles or smallpox, the Ice Bucket Challenge spread quickly across the world as nominees became immediately “infectious” once nominated. A previous social network experiment found that individual uptake improved with reinforcing signals from clustered social ties.<sup>18</sup> Therefore, specified nominations within

a social network, such as celebrities, may be more successful in spreading promotional messages for public health interventions than are generic nominations. However, whether such social networks should be leveraged for health communication depends on the nature of the intervention.<sup>19</sup> Finally, our findings suggest that the  $R_0$  of a social media campaign may increase with the support from people of a high net worth, independent of age or sex.

## Limitations of this study

We had limited power to detect differences in  $R_0$  for personal factors as the inclusion criteria restricted the number of eligible index cases. Reporting of the Ice Bucket Challenge might have been socially patterned, contributing to potentially biased associations between transmissibility and net worth. The epidemiological assessment is based on a non-representative sample, and generalisability to other population groups is limited. We did not account for the likely broader influence<sup>19</sup> of our cohort of global celebrities on the much larger population of fans and followers worldwide (average of 6.5 million Facebook likes per cohort participant), thus underestimating the overall  $R_0$ , analogous to the “super spreader” concept.<sup>20</sup>

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Contributors: MYN conceived the study, wrote the initial protocol, collected data, and wrote the first draft of the manuscript. BHYC developed the protocol and collected data. EHYL, HP, MYN, and GML analysed and interpreted the data. All authors critically revised the final manuscript, had access to the full dataset, take responsibility for the integrity of the data and the accuracy of the dataset, and gave final approval for the submission of this version for consideration of publication. EHYL and HP contributed equally to the work. MYN and BHYC are guarantors for the study.

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Competing interests: All authors have completed the ICMJE uniform disclosure form at [www.icmje.org/coi\\_disclosure.pdf](http://www.icmje.org/coi_disclosure.pdf) (available on request from the corresponding author) and declare: no support from any organisation for the submitted work; no financial relationships with any organisations that might have an interest in the submitted work in the previous three years; no other relationships or activities that could appear to have influenced the submitted work.

Ethical approval: Not required.

Data sharing: The dataset is available at the Dryad Digital Repository (provisional doi:10.5061/dryad.n4sc4).

Transparency: The lead author (MYN) affirms that this manuscript is an honest, accurate, and transparent account of the study being reported;

that no important aspects of the study have been omitted; and that any discrepancies from the study as planned (and, if relevant, registered) have been explained.

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**What is already known on the topic**

Numerous reports have suggested that the Ice Bucket Challenge has gone "viral"

Until now formal analysis of its transmissibility has been limited

**What this study adds**

The Ice Bucket Challenge was moderately transmissible among global celebrities and their nominees

Higher net worth may be associated with greater transmissibility

## Tables

**Table 1 | Personal information, individual  $R_0$ , and total number of successful contacts of celebrities taking part in the Ice Bucket Challenge in each nomination chain up to fifth generation for each index case**

Index case	Age (years)	Profession	Net worth (\$000 000)	$R_0^*$	Total No of successful contacts
David Beckham	39	Sports	350	3	10
Cristiano Ronaldo	29	Sports	250	1	13
Benedict Cumberbatch	38	Artist	15	2	7
Stephen Hawking	72	Scientist	20	2	2
Mark Zuckerberg	30	Entrepreneur	33 300	3	41
Oprah Winfrey	60	Entrepreneur	2900	3	20
Homer Simpson	Unknown	Nuclear safety inspector	Unknown	1	1
Kermit the Frog	Unknown	Entertainer	Unknown	1	1

\*Measure of transmissibility.

\$1.00 (£0.64; €0.81).

**Table 2| Association of personal characteristics with basic reproduction number\* (R0), in the celebrities based cohort of the Ice Bucket Challenge, 2014**

Characteristics	Odds ratio (95% CI)
Age (years)	1.01 (0.98 to 1.04)
Female sex	0.80 (0.38 to 1.68)
Occupational sector:	
Arts	Reference
Business	2.23 (0.89 to 5.59)
Government	1.39 (0.11 to 18.0)
Sports	1.15 (0.34 to 3.93)
Science	0.51 (0.09 to 3.10)
Log (net worth)	1.63 (1.06 to 2.50)
Log (Facebook likes)	1.23 (0.87 to 1.72)
Log (Twitter followers)	1.46 (0.96 to 2.22)

\*Measure of transmissibility.

**Table 3| R<sub>0</sub> (major determinant of size of epidemic) of Ice Bucket Challenge and other contagions**

Contagion	Period of event/outbreak	R <sub>0</sub>	Mean serial interval (days)
Ice Bucket Challenge*	2014	1.43	2.1†
Pandemic influenza	2009	1.2-2.3 <sup>21</sup>	2.8 <sup>21</sup>
MERS-CoV	2012-14	0.5-1.3 <sup>22-24</sup>	9.6‡ <sup>25</sup>
Measles	Recurring	14-18 <sup>26</sup>	11.7 <sup>21</sup>
Smallpox	Before 1980, eradicated	4-10 <sup>7</sup>	17.7 <sup>21</sup>

MERS-CoV=Middle East respiratory syndrome coronavirus.

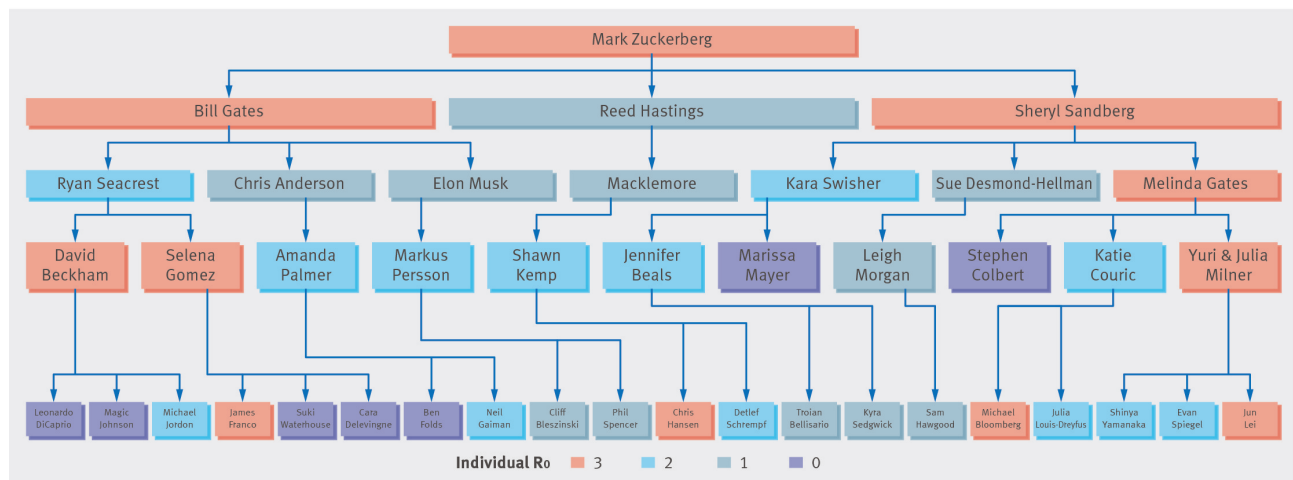
R<sub>0</sub> values >1 represent a self sustaining epidemic.

\*Based on data in current study only.

†Median serial interval was 1 day.

‡Derived mean from fitted log normal distribution.

## Figure



Tree structure of nominations associated with index case Mark Zuckerberg