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EFFECTS OF EDUCATION AND MEDIA FRAMING ON GENETIC KNOWLEDGE AND ATTITUDES

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Abstract

Genetic education is paramount to continued genetic advances, as well as for beneficial use of the outcomes of such advances. However, a large body of literature suggests that the public's genetic literacy remains inadequate. Previous research has found a positive relationship between educational level and genetic literacy. The current research explores this in 2 samples of UK students: school (A-Level) and undergraduates. A between groups ANOVA revealed a significant difference in genetic literacy scores between the educational levels. The current study further explored genetic literacy of Psychology undergraduates, as psychologists are likely to play a key role in the genomic era, for example contributing to genomic research and providing genetic counselling. Results revealed low genetic literacy in Psychology undergraduate students, highlighting the need for genetic education improvements. To this end, experimental manipulations were conducted to investigate the effects of media framing and feedback on views of genetic determinism and knowledge calibration. A between groups ANOVA showed no significant difference between high and low determinism media framing. The knowledge calibration findings suggested that participants were underconfident in their genetic knowledge. No correlation was found between knowledge and perceived knowledge (confidence) in the group of participants who received feedback. In contrast, a positive correlation between knowledge and confidence was found in the no-feedback condition. Future research is needed to build on these findings.

Keywords: Knowledge Calibration, Genetic Literacy, Psychology Undergraduates, Science Communication, Media Framing.

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1. Introduction

Developments in science and technology, both their independent and collective implications, permeate the culture and politics of modern day citizenship. As Fischhoff (2013) argues, whilst people can elect not to *do* science, they cannot elect to ignore it. Following the completion of the Human Genome Project in 2003, there have been subsequent profound developments and discoveries in genomic science. For example, in 2013, the government demonstrated its confidence in the merits of increased genomic information by its investment of £200 million in the genome sequencing of 100,000 National Health Service (NHS) patients. The aim of the 100,000 Genomes Project is to create a new genomic medicine service for the NHS, which will improve and transform personalised treatments, and potentially offer patients a diagnosis which hasn't been previously available (Genomics England, 2014). Furthermore, the UK genomics industry currently contributes around 10% to the global market (£0.8 billion), but is set to outpace the global market, increasing at a 20% compound annual growth rate (CAGR), due to investments and national projects (Deloitte, 2015). The emerging ramifications in the "post genomic era" (Duyk, 1999) require the need for genetic literacy.

Genetic literacy can be defined as the working knowledge of genetics and related areas, including genomics, pharmacogenomics and gene therapy (Carver et al., 2017). Despite the extensive advances in genomic data via novel analytical approaches and technologies (Zhao and Grant, 2011), and genetic issues playing a considerable role in public health policy (Burton, Jackson and Abubakar, 2014), the public's genetic literacy is still lacking (Mills Shaw, Horne, Zhang and Boughman, 2008; Miller et al., 2006; Bowling et al., 2008). Genetic education research has highlighted genetic understanding to be particularly low in school students (e.g. Saka et al., 2006; Duncan, Rogat, and Yarden, 2009; Duncan and Reiser, 2007). More specifically, research has shown students have distinct misconceptions about basic concepts (e.g. Venville and Treagust, 1998; Lewis and Kattman, 2004). A lack of understanding means individuals will be unable to make informed judgments about genetic diagnoses, or the implications of lifestyle choices for personal health and that of offspring; therefore genetic knowledge seems increasingly to be a prerequisite for modern citizenship (Marks, 2016).

Research has identified mass media and formal education as two of the main gateways of scientific information from the scientific community to the public (see Figure 01; and also Wellington, 1994; Falk, Storksdieck and Dierking, 2007; Wellington and Osborne, 2001). Research has also shown that the informal presentation of genetic information, used by the media, is often inaccurate (Lanie et al., 2004). In 2000, the UK government issued an official calling for initiatives to improve science communication to the public. This report was, for the most part, a consequence of concerns that the public's confidence in science had dramatically decreased following scientific issues (such as genetically modified crops) receiving misleading media coverage (Carver, 2014). Academic institutions established the introduction of academic programmes at both undergraduate and postgraduate level in science communication (Mulder, Longnecker and Davis, 2008). Consequently, a vast body of literature has grown concerning science communication, which has focused on the media's presentation of scientific information (e.g. Eyck and Williment, 2003; Petersen, 2001; Nisbet and Mooney, 2007).

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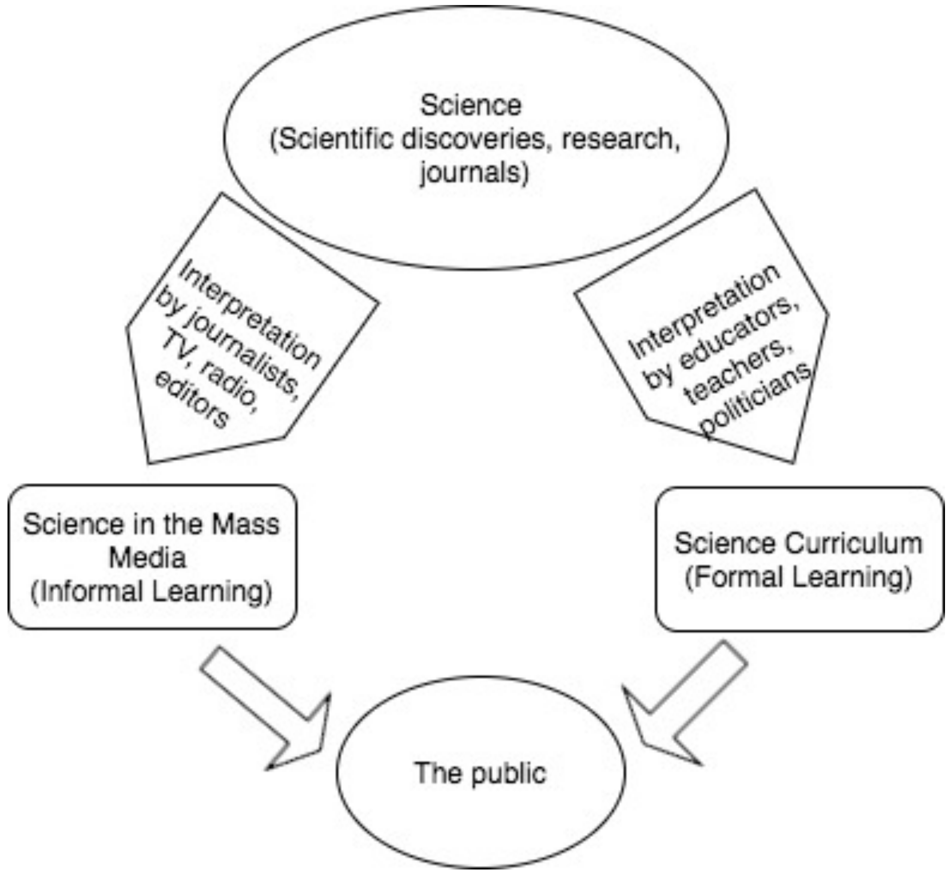

Figure 01. A visual presentation of the science communication filtering system between the scientific community and the public. Adapted from Wellington (2008).

1.1. Media Framing Effects

Advances in genetics and genomics have generated the understanding that complex traits form under the influence of a myriad of genetic and environmental factors (Bubb and Queitsch, 2017). Consequently, the science community has adopted a more probabilistic understanding of the relationship between genes and phenotypes (observed traits), with the ‘nature versus nurture’ debate becoming outdated (Levitt, 2013; Castera and Clement, 2014). Even single mutation gene disorders cannot be explained easily. A typical gene consists of thousands of base pairs, any of which are subject to mutation. Mutations in the same gene in different people may lead to: no disorder at all – *reduced penetrance*; disorder of different level of severity – *variable expressivity*; different combinations of symptoms; or disorder manifesting at different ages (Pradhan, Agarwal and Prasun, 2007). Only multiple interactions between genome, environment and organism can explain the observed biological complexity (‘the triple helix’, Lewontin, 2000). Despite recent advancements undermining the very premise of determinism, a wealth of literature suggests that genetic deterministic beliefs are prevalent (Gould and Heine, 2012; Gericke and Smith, 2014; Dar-Nimrod and Heine, 2011). The exact boundaries of genetic determinism are difficult to conceptualise. For the purpose of this study, genetic determinism is defined as the attribution of genetic causality, in a total manner, such that it disregards epigenetic, environmental and probabilistic input (Condit, 1999). In other words, genetic determinism is the reduction of the human being to a molecular entity, and equating the self to one’s genes (Conrad, Nelkin and Lindee, 1996).

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Extensive research has found the mass media to be the public's main source of scientific information following formal education (Eyck and Williment, 2003; Holliman, 2004; Condit, 1999). Similarly, the Wellcome Trust Monitor (2014) found that, whilst public interest in genetics remains high (e.g., 77% indicating interest in medical research), most people access genetic information passively rather than actively. This highlights the importance of the requirement for a standard of quality and quantity of scientific information, which are crucial in shaping public knowledge, opinion and reactions (Picard and Yeo, 2011; Bultitude, 2011; Medin and Bang, 2014). The media often creates simplified accounts of genetic research placing a stronger emphasis on genetic (rather than gene-environment) explanations. These explanations are in line with a typical lay-person's intuitive essentialism, which is often an incorrect belief about how genes function (Bubela and Caulfield, 2004; Young, Ioannidis, Al-Ubaydli, 2008; Dar-Nimrod and Heine, 2011).

Academics have reported concerns about deterministic and discriminatory public attitudes towards genetics as a result of media coverage (Conrad and Weinberg, 1996; van Dijck, 1998, Lynch, Bevan, Achter, Harris and Condit; 2008). For example, research identified that genetic misconceptions in children as young as 10 years old paralleled themes from their media activity (Donovan and Venville, 2012). Additionally, research into lifelong science education has found that informal methods of learning (such as the mass media) take precedence over formal education (Rundgren, Rundgren, Tseng, Lin and Chang, 2010; Bajrami, Reci and Iseni, 2016). University science students have been found to have poor evaluation and interpretation of the quality of typical science media reports (Norris, Phillips and Korpan, 2003). Interestingly, even the highest performing science students struggled with this task (Norris and Phillips, 2003), which demonstrates the complex nature of science communication and inference. Overall, these findings have led to a number of investigations into how to educate students to be able to critically evaluate mass media science reports (Jarman, McClune, Pyle and Braband, 2012).

In recent years, a concept of "media framing" in science communication has attracted research interest. A "media frame" is the result of critical words, phrases, metaphors and other forms of textual materials manifesting in media content (Cavaar, 2013). Entman's (1993) description clarifies that media framing is based on selection and salience; it is the selection of certain aspects of a perceived reality and an enhancement of their salience via communicative text. Media framing has been found an important factor in affecting accuracy of transmission of science information to the public (Nisbet and Mooney, 2007; Reis, 2008). Research into public interpretation of media framing in news articles tends to merge the effect of the headline and accompanying article. However, research suggests that these should be viewed as having independent contributions. For example, even if the article content is less deterministic than the headline, the headline might act as a significant influencing framing device (Sheedy, 2000). It is easy to see how such headlines as "*Schizophrenia gene remains elusive*" and "*Crime in the family tree*" can lead to a deterministic interpretation of the material (Hubbard and Wald,1993). Moreover, a large proportion of individuals only read the headline and not the main article (Sheedy 2000).

Research has also suggested that readers, who receive a headline containing a negative connotation without reading an accompanying article, rate the story more negatively than those who read control headlines (Wegner et al., 1981). However, the results of the previous literature are not consistent. For example, one study with college students, used three conditions: no headline; highly deterministic headline; or a less deterministic headline. All three groups read the same abridged version of a news article on genetic research into diabetes (Condit et al., 2001). The article was deliberately selected for low genetic determinism. Results found equally low levels of genetic determinism in the three groups. Therefore, those exposed to highly deterministic headlines did not experience increased post-deterministic tendencies, compared to those exposed to no headline or low determinism. These results challenge the headline-framing hypothesis proposed by Sheedy (2000). It is possible that the study was underpowered to find small effects of media framing. Moreover, most articles about genetics contain a mix of deterministic and less deterministic statements (Condit, Ofulue and Sheedy, 1998). It is possible that headline framing effects may function through activating selective perception (Pfau, 1995), and therefore could be more pronounced in a mixed deterministic content (Condit et al., 2001).

Research indicates that the impact of framing is dependent on: (a) the degree of exposure (e.g. duration, repeated exposure); and (b) prior knowledge (Waldahl, 2007). Lower knowledge on a particular subject is associated with stronger framing effects (Bubela et al., 2009; Scheufele and Tewksbury, 2007). Less knowledge may render the individual more likely to depend on cognitive heuristics, emotions and values disseminated in the media frame (Bubela et al., 2009).

1.2. Actual and Perceived Genetic Knowledge

It is widely acknowledged that advances in genetic and genomic science have, and will continue to have, a major impact on healthcare systems. A transition from disease-orientation to risk-orientation will enhance diagnosis, treatment, prediction and prevention (International Council of Nurses, 2005). This will have repercussions for all individuals who utilize the healthcare system, from patients to healthcare practitioners (Morren, Rijken, Baanders and Bensing, 2007). However, growing concerns speculate whether true clinical utility can be met if patients do not understand the significance of genomic and genetic information (Rogowski et al., 2009; Yang et al., 2009). The foundations of established genetic literacy in the general public begin in formal education (Rogowski et al., 2009).

"Gene concept" is seen as the foundation knowledge for further genetic literacy and is therefore the core for genetics education in the biology curriculum (Duncan and Reiser, 2007; National Research Council, 1996). In spite of this, research has indicated that understanding the gene concept presents a marked difficulty for learners and teachers (Knippels, Waarlo, and Boersma, 2005; Lewis, Leach and Wood-Robinson, 2000; Marbach-Ad and Stavy, 2000). Similar findings emerged in studies with undergraduate students. For example, one study found a marked difficulty in undergraduate students with linking concepts in genetics, with students' conceptions of genetics differing from the current model of heredity (Agorram et al., 2010).

Research with medical professionals also raises concerns about the level of their genetic literacy (Brantl and Esslinger, 1962; Burke and Kirke, 2006; Lea and Monson, 2003). For example, a large body of research has highlighted weaknesses in genetic knowledge of nurses and midwives (e.g. Bankhead et al., 2001; Kim, 2003; Talwar et al., 2016; *see systematic review* Godino and Skirton, 2012). One study surveyed a large sample (n=605) of nurses and midwives, and discovered widespread confusion and a lack of confidence in the practitioner's role with regard to genetics (McGregor, 2005). Similarly, research found gaps in self-perceived genetics knowledge and confidence of in neurologists and psychiatrists (Salm et al., 2014).

In addition, research has highlighted increasing requirements for genetic knowledge (to varying degrees) in interdisciplinary medical teams, including social workers, occupational therapists, psychologists and psychiatric nurses (Elphick, 2013). For example, increased use of genetic counselling provides a new interdisciplinary occupational field for nurses, psychologists, scientists and other professionals, and calls for greater genetic literacy among these professionals (Kenen, 1984; McAllister et al., 2015; Hannig et al., 2013; Austin and Honer, 2007). Genetic counselling is an emerging profession in Europe that works to facilitate patient decision-making and consequent adaptions to a genetic diagnosis in the family (McAllister, Moldovan, Paneque and Skirton, 2015). The rapid increase of genetic tests in mental health care will further contribute to genetic counselling demands (Mrazek, 2010; Mitchell, 2011; Hoop, Roberts, Hammond and Cox, 2008).

The reviewed research demonstrates the widespread lack of genetic knowledge in the population. Another problem is people's failure to recognize their own lack of knowledge. Research suggests that healthcare professionals are more aware of their knowledge deficits than laypersons, who utilise genetic terminology without an appropriate understanding of genetics terminology (Lanie et al., 2004). A large body of literature suggests that only a modest relationship exists between actual knowledge and perceived knowledge (Radecki and Jaccard, 1995; Blanton, Pelham, DeHart and Carvallo, 2001). Knowledge calibration describes a phenomenon whereby an individual pairs confidence in their knowledge accurately with their actual knowledge (Alba and Hutchinson, 2000). Measuring calibration requires an actual or objective knowledge assessment and reported confidence or subjective measure of knowledge. Literature demonstrates that people exaggerate personal expertise favourably (e.g., Atir, Rosenzweig and Dunning, 2015). This "illusion of knowing" may keep people from identifying a requirement to improve their genetic literacy (Lanie et al., 2004). Given the rising demand to be genetic and genomic literate, and the complex nature of the field, accurate genetic knowledge calibration is also required to ensure motivation and commitment to furthering ones understanding (Pearson and Liu-Thompkin, 2012).

Knowledge calibration provides critical insights into the relationship between knowledge and self-efficacy (one's belief in their ability to accomplish a task in a specific domain; Bandura, 1982) (Pearson and Liu-Thompkin's, 2012). There are various ramifications of knowledge calibration or miscalibration. For example, an underconfident individual may seek vast quantities of external information on genetics and (as previously discussed) this could present problems given that mass media information can be inaccurate (Condit et al., 2010).

Research also highlights that subjective assessment of genetic knowledge is positively correlated with attitudes towards genetics (Morren et al., 2007). One of very few studies on genetic knowledge calibration showed that university students had low-level genetic literacy, but contrary to previous findings of overconfidence, the students had a tendency toward under confidence in genetic knowledge (Pearson and Liu-Thompkin, 2012). In this study, life science students performed significantly better on genetic literacy, and their confidence was significantly higher than non-life sciences students. However, life science students did not show more accurate calibration scores than other participants. The study also found that feedback can reduce knowledge miscalibration. These findings support existing literature that feedback has beneficial effects on confidence (Ashford, Blatt and Vande Walle, 2003).

2. Problem Statement

This study aims to address some of the gaps in the existing literature. A wide body of literature has demonstrated that school students exhibit particularly low genetic knowledge (e.g. Bowling et al., 2008), However, there is only limited research on the genetic literacy of undergraduate students, particularly in the UK. This demographic is critical as the future users of genetic developments.

Previous research has highlighted that higher education leads to improved genetic literacy (e.g. Calsbeek, Morren, Bensing and Rijken, 2007; Haga et al., 2013). However, the measure of education level in previous studies has often been collected retrospectively, which complicates conclusions regarding the effect of higher education. For example, individuals selecting 'undergraduate degree' as their highest obtained level of education vary greatly in how much time has passed since their graduation. Therefore, it is not possible to evaluate whether it is higher education per se that leads to better genetic literacy, or whether there are other age related contributing factors, such as exposure and experience. Therefore, research is needed to test whether those *currently* pursuing higher education exhibit on average better genetic literacy than those *currently* completing lower level education.

In addition, Psychology undergraduate students present a particularly interesting group for investigation. There is a notable dearth of literature on *psychology* student's genetic knowledge, in comparison to students in medical fields. However, psychology students are a crucial demographic as they are likely to be facilitators of genetic advances in the population (Laegsgaard and Mors, 2008). Rapid developments in the behavioural genetics field (Kruger, Korsten and Hoffman, 2017) and subsequent findings of functionally relevant candidate genes for various mental-health disorders (e.g. Soronen, 2012; Gibson et al., 2017) provide new roles to psychologists in the genomic era.

Finally, focusing on young adults allows for an investigation into how prepared they are for parenthood in the genetic era. Research is needed to assess the level of young people's understanding of issues related to prenatal testing, newborn screening and probabilistic prediction.

3. Research Questions

The present study has 3 main aims. First, to identify whether a significant difference in genetic knowledge exists between current UK A Level and undergraduate students. Second, to explore the effects of media framing on post-exposure self-reported views on genetic determinism. Third, to investigate whether feedback improves genetic knowledge calibration.

- **Hypothesis 1:** Current undergraduate students (higher educational level) will demonstrate better genetic literacy compared to current A-Level students (lower educational level).
- **Hypothesis 2**: Media framing will have an effect on self-reported deterministic attitudes towards genetics.

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- **Hypothesis 3:** Greater knowledge miscalibration will on average be observed in participants who receive feedback after rating how confident they are in their genetic knowledge, than those who receive feedback before reflecting on their knowledge.

4. Purpose of the Study

The ultimate goal of this study is to provide new insights into factors affecting genetic literacy acquisition, including education, media framing and feedback. Better understanding of these factors will lead to more accurate and efficient transferal of scientific information from the science community to the general population. This will ultimately lead to a more genetically literate population, better equipped to function in the genomic era.

5. Research Methods

5.1. Participants

To determine whether the education level groups differ in their genetic knowledge (Hypothesis 1), the International Genetic Literacy and Attitudes Survey (iGLAS) was administered to an opportunity sample of 153 undergraduate (126) and A Level (27) students (113 females, 39 males, 2 non-binary), aged between 16-51 years (M = 20.12 years, SD = 5.41 years). The participants were ethnically and culturally diverse. Undergraduate and A Level students completed the survey separately.

For the experimental part of the study (Hypotheses 2 and 3), only data from the undergraduate participants were used. This volunteer sample included 96 females, 28 males, and 2 non-binary participants, aged between 18-51 (M = 20.89 years, SD = 5.66 years). All participants were first year Psychology undergraduate students who were recruited via the Psychology Department Research Participation Scheme in exchange for a course credit.

5.2. Study Design

The study included an exploratory part (Hypothesis 1) and an experimental part (Hypotheses 2 and 3). Figure 02 presents the design of the 2 experiments.

Experiment 1: A between participants design was used. The independent variable was word cloud (high-determinism or low-determinism) and the dependent variable was post-exposure self-reported views on genetic determinism.

Experiment 2: A between participants design was used. The independent variable was feedback (feedback or no-feedback) and the dependent variable was self-reported confidence in genetic knowledge.

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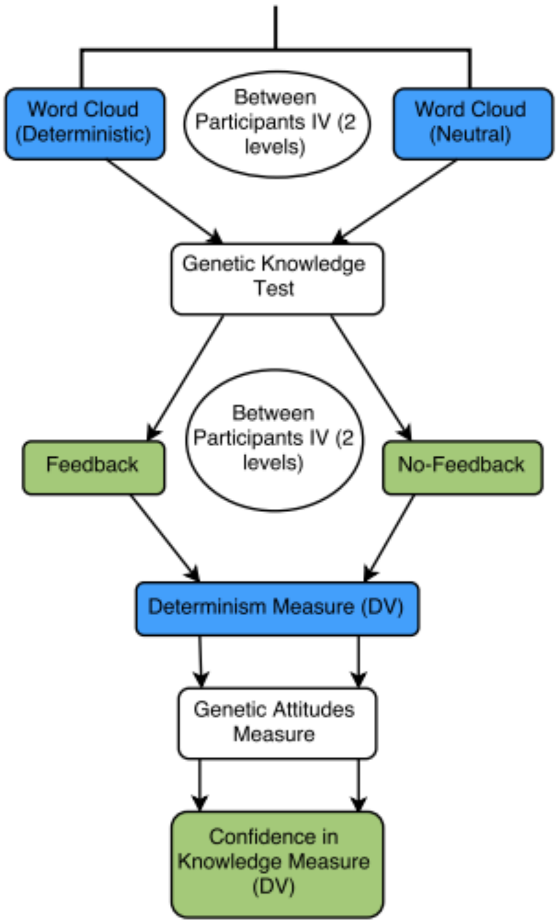

Figure 02. Presentation of experimental design; blue is experiment 1 and green is experiment 2

5.3. Materials, Measures and Variables

5.3.1. Word Cloud

Word clouds are a visual representation of the frequency tabulation of the words in a selected piece of text (Miley and Read, 2012). The *word cloud* method was employed in this study to increase the salience of the particular words and phrases (as suggested by Condit et al., 2001), much like would be interpreted from skim reading (Fatmawati, 2014). Two word clouds were generated using online newspaper articles (See Figure 03), with the most repeated words from each article appearing as larger words in the cloud. Online articles were chosen as the mass media platform for the experiment, as they are a widespread, relatively in-depth source of information for the public (Cavaar, 2013; Jarman and McClune, 2007). To retrieve genetics related articles, a search for "genes online article UK" was conducted. Only National broadsheet papers were considered because they address the broader society and are representative of genetic information being presented to society. Two broadsheet articles were selected, similar in topic and length: "Genes influence academic ability across all subjects, latest study shows" (Guardian); and "Genetic screening of pupils would herald a Huxleyan nightmare" (Telegraph). The Telegraph article fitted the hypothetical *deterministic media frame*: seeing genes as the definite cause for a trait (e.g. Nelkin and Lindee, 1995). The Guardian fitted the hypothetical *gene versus* environment *media frame*: which focuses on the effects of nature and nurture separately (e.g. Condit, 2007).

Figure 03. Word clouds for the high determinism (Left: Telegraph) and low determinism (Right: Guardian) conditions.

The word clouds were created on www.wordclouds.com. From the Telegraph text, "Brave New World" was removed, as social familiarity may lead to response bias. As media framing requires a certain exposure time to be effective (Buturoiu and Corbu, 2015), each participant was presented with their word cloud for exactly 60 seconds.

Prior to the experiment, a manipulation check was carried out on a separate group (n=8) of a similar demographic profile, to test whether the two word clouds were significantly different in their level of determinism (as suggested by Condit et al., 2001). Participants were asked to answer for both word clouds: "what word best describes the authors conclusion about the relationship between genes and intelligence", on a scale of 1 to 4, where 1 = unrelated, 2 = associated, 3 = predisposing and 4 = cause. The two clouds were found to be significantly different: high determinism: mean=3.38, SD= .518; low determinism: mean = 1.50, SD = .535 (t = 7.94, df = 7, p = < .05).

5.3.2. Genetic Literacy

The present study used The International Genetic Literacy and Attitudes Survey (iGLAS; Chapman et al., in press) developed by The Accessible Genetics Consortium (TAGC). iGLAS consists of 3 parts: knowledge, opinions, and a demographic survey. In addition, participants also completed a personality measure (shortened Big Five inventory; Rammstedt and John, 2007). Questions were formatted in a variety of ways including: Yes/No, multiple choice, Likert and slider scales - to help reduce the effects of Common Method Variance (Lindell and Whitney, 2001). The number of knowledge questions answered correctly (out of 18 total), was transformed into a percentage score, which functioned as a genetic literacy indicator.

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5.3.3. Feedback

Feedback was provided as a total raw score of correct answers, e.g. 12/18. As detailed feedback on each item was not provided, this feedback was non-informative. The presentation position of feedback, as per the design detailed in Figure 02, resulted from a random computerized allocation used in Qualtrics (see Figure 02).

5.3.4. Determinism

Determinism measure was calculated by the question "*I believe that my destiny is written in my genes"* on a 1-7 Likert scale ranging from strongly disagree to strongly agree.

5.3.5. Confidence

Respondents were asked to measure their confidence in their genetic knowledge on a continuous scale between 0-100, as is common practice in task specific self-efficacy research. The use of continuous scale in online surveys has been found valid and reliable (Neibecker, 1984; Treiblmaier and Filzmoser, 2009). Confidence was only measured as task-specific, and only one measure was taken due to time limitations (*see limitations in discussion).*

5.3.6. Knowledge Calibration

In line with previous research on judgment accuracy (Schraw and Roedel, 1994; Pearson and Liu-Thompkin, 2012), knowledge calibration score was calculated by the total difference between genetic knowledge score and reported confidence in genetic knowledge. To make genetic knowledge score comparable to reported confidence, it was translated into a percentage; such that answering 9 out of 18 questions correct would be 50%. The absolute difference between the actual knowledge and perceived knowledge (confidence) indicates miscalibration, where a positive integer is overconfidence and a negative integer is under confidence.

5.4. Procedure

Ethical approval was obtained from the Ethics Committee, Goldsmiths, University of London.

All participants were tested in a single session in a large lecture theatre. Participants attended the session in exchange for course credits. Participants were emailed prior to the study and asked to bring to the testing session a smart device (phone, laptop, tablet etc.) to complete the experiment. The survey was administered via one of two URL webpages or QR codes. The experiment was run on www.qualtrics.com. Using an unstandardized sample splitting technique, half of the participants were told to open one of the URL's or QR codes (high-determinism media framed word cloud), the other half was told to open the other URL or QR code (low-determinism media framed word cloud).

Participants were told not to confer with one another during the experiment so that results were not contaminated. Once they opened the specific link or QR code, participants were taken to the informed consent page; this included contact information for the researcher and supervisor. It also included confidentiality and withdrawal information. Once participants had given informed consent, they would

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receive instruction on the upcoming word cloud exposure (see Figure 03). Given that word clouds are a relatively innovative and novel way of communicating information, concise instructions were given to the participants to avoid confusion and enhance effectiveness. As was made clear to the participant in the word cloud instructions, participants would be required to provide a brief summary of what they thought the article (from which the word cloud was generated) was about after viewing it. This was done to ensure that they paid attention to the cloud and attempted to interpret it. After completing this task, participants moved onto the genetics knowledge section of the survey.

Using the "randomizer element" on Qualtrics, half of the participants were assigned to receive genetic knowledge feedback immediately after completing the section; the other half did not receive the feedback at this time. All participants then moved onto the attitudes section, which includes the genetic determinism and self-perceived confidence in knowledge measures. Afterwards they completed the personality and demographic measures. Following completion of the demographic survey, the other half of the participants received their genetic knowledge feedback. Then all participants received a debrief form which provided contact information for any further questions.

6. Findings

6.1. Data Cleaning

Three participants had not brought smart devices with them; they completed the the paper version of the survey, so they could receive a course credit. The data from these participants were excluded from the analyses, as they could not receive genetic knowledge feedback.

6.2. Educational Level

A between participants ANOVA was conducted to compare the effect of education level on genetic knowledge between the A Level students (M = 9.34, SD = 2.29) and the undergraduate students (M = 10.71, SD = 2.71). There was a significant difference between the groups (F (1, 154) = 6.32, p = 0.013). These results suggest that those currently completing a higher educational level of University exhibit higher genetic literacy scores than those at a lower educational level (second year A Level).

6.3. Genetic Literacy of Psychology Undergraduates

The respondents' genetic knowledge score ranged from 22.2% to 94.4% and the average was 60.17%. Females performed marginally worse on the genetic knowledge test (M = 10.67%, SD = 2.46%) than males (M = 11.39%, SD = 2.46%). A Pearson correlation coefficient was used to assess the relationship between age and genetic knowledge. There was no correlation between the two variables, (r = .054, n = 126, p = .548).

6.4. Genetic Determinism

A one-way between participant ANOVA was conducted to compare the effect of word cloud on genetic determinism, in the high-determinism and low-determinism conditions (see Table 2 for means and standard deviations). No significant effect of word cloud on genetic determinism was found (F (1,125) = 1.14, p = .287). These results suggest that post-exposure attitudes were not more deterministic in those who were exposed to the high-determinism word cloud than in those who were exposed to the low-determinism word cloud.

Table 01. Means and Standard Deviations for reported Genetic Determinism following presentation of High-determinism or Low-determinism word cloud.

Determinism	N	Mean	Standard Deviation
High	60	3.03	1.45
Low	67	2.76	1.42

6.5. Genetic Knowledge Calibration

Table 02. Percentages of Average Genetic Knowledge, Confidence and average miscalibration in Feedback and No Feedback groups

Feedback	Average Genetic Knowledge (%)	Average Confidence in Genetic Knowledge	Average miscalibration
Yes	59.72	32.92 (SD = 20.30)	-27.16 (SD = 21.85)
No	60.67	38.98 (SD = 24.21)	-21.69 (SD = 22.97)

As evidenced by the negative calibration score, all participants were underconfident in their genetic knowledge in both the feedback (M = -27.16, SD = 21.8) and the no feedback (M = -21.69, SD = 22.97) conditions (Table 02).

All participants showed poor genetic knowledge calibration reporting lower confidence scores than their actual genetic knowledge scores. An independent samples t-test was conducted to compare miscalibration scores in the feedback group and no feedback group. There was no significant difference in the scores for the feedback and the no feedback conditions; t(124) = -1.52, p = .130). These results suggest that feedback does not have a significant effect on reported confidence in genetic knowledge.

A Pearson product-moment correlation coefficient was computed to assess the relationship between genetic knowledge and confidence in genetic knowledge. In the feedback condition, there was no significant correlation between the two variables (r = 0.237, n = 63, p = .062). In the no feedback condition, there was a significant positive correlation between the two variables [r = .408, n = 63, p = 0.001].

7. Conclusion

Scientific knowledge on genetics and genomics is increasing at a rapid pace. However, this has not yet translated to an improved genetic literacy in A Level or undergraduate students. The results of this study demonstrate that both A Level and undergraduate students are underperforming in their genetic knowledge scores. These results are in line with a wide body of literature (e.g. Bowling et al., 2008; Agorram et al., 2010).

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The ANOVA revealed a significant difference in genetic literacy scores between the educational levels. These results provide further support to previous research, which have demonstrated a positive relationship between educational level and genetic knowledge scores (e.g. Calsbeek et al., 2007; Haga et al., 2013). Second year A-level students are only 1 year away from being Undergraduate students and should arguably have 'fresher' knowledge of biology and genetics, as covered by the compulsory curriculum. Moreover, most of the A-Level students in this study are likely to progress to University as they were recruited for the study whilst attending a university open day. It is therefore remains unclear why University students outperform their only slightly younger peers. Further research is needed to explore factors that explain why higher educational level leads to increased genetic literacy score. The findings also require replication, as the sample size of A Level students was small.

The second aim of this paper was to investigate whether a deterministic-framed word cloud would affect subsequent self-reported deterministic attitudes towards genetics. This is an important area of research, given the wealth of literature suggesting that the mass media is the main source of scientific information for the public after formal education (e.g. Eyck and Williment, 2003). The results suggest that word cloud exposure does not significantly affect deterministic views. There was no significant difference in deterministic views (following exposure to the word cloud) between the two groups (high determinism vs. low determinism). Whilst this finding is in line with previous literature (e.g. Condit et al., 2001; Condit et al., 2004), its generalisability must be considered against several limitations. First, the presentation of the news article, using a word cloud, was not a typical method of communication, particularly not for a newspaper article. The strict instructions given to participants, that they would have to subsequently describe the word cloud, might have resulted in lower ecological validity, as such a requirement would not be made of skim readers in a real life situation (Pannucci and Wilkins, 2010). The use of word clouds was chosen as a means of presenting fewer, more salient words, much like the interpretation one would expect from a skim-reader (Rayner et al., 2016). Investigation of skim readers is important as this is a style of reading often adopted by Internet users (Duggan and Payne, 2011), and as the Internet is often a source of over-simplistic genetic concepts (Kampourakis, 2017). However, the results suggest that this form of 'media framing' does not have a significant effect, at least on determinism. Future research is needed to investigate other forms of media framing in student populations.

Additionally, some researchers have reported an interaction between linguistic text structure and prior knowledge (McNamara, Kintsch, Songer and Kintsch, 1996; McNamara, 2001). Readers with a deeper prior knowledge would better interpret or "benefit" from an implicit text, whereas readers with less prior knowledge would perform better on text comprehension following explicit versions of text. Therefore, interpretation of the implicit/reduced information provided in the word cloud might have been particularly problematic for those with less prior knowledge.

Future research should extend to include university students of other disciplines, as well as different ages and birth cohorts. Young adults are immersed and arguably dependent on the mass media, which acts as a gateway to social networking, education and political participation (Towner and Lego Munoz, 2016). Whereas, older people on average spend more time watching television (Bureau of Labor Statistics, 2016; Moody, 2016). Moreover, more recent birth cohorts may be fundamentally different in

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media use from earlier cohorts of the same age. Given the tendency to utilize different platforms of media, it is important to establish any potential differences in genetic attitudes between ages and cohorts.

The third aim of this paper was to investigate Psychology undergraduate students' genetic knowledge and the accuracy of their genetic knowledge calibration. The study also explored whether feedback would improve genetic knowledge calibration. These research questions are important as very few previous studies focused on this particular demographic. Previous research (Lanie et al., 2004) suggested that " illusion of knowing" can hinder people's ability to recognise a necessity for genetic literacy improvement and discourage individuals from seeking more information (Park, 2001).

The results of the present study showed that miscalibration scores in both the feedback and the no feedback conditions reflect underconfidence in participants' genetic knowledge. These findings are consistent with some research (e.g., Pearson and Liu-Thompkin, 2012), but not other studies that demonstrated overconfidence (e.g. Alba and Hutchinson, 2000). Overall, the results support previous findings of self-perceived level of knowledge being frequently inaccurate (Lichenstein, Slovic and Fischoff, 1977).

There was no significant difference between feedback (-27.16%) and no feedback (-21.69%) conditions, therefore the hypothesis was not supported. Moreover, a positive correlation was found in the no-feedback condition ($r = .408$) between genetic knowledge and confidence in knowledge, whereas no significant correlation ($r = 0.237$) was identified in the feedback condition. This further highlights the lack of support for the original hypothesis. The higher miscalibration score in the feedback group was unexpected, as feedback would provide participants with a clearer indication of their genetic knowledge. Furthermore, previous literature suggests individuals are typically more accurate at postdictions rather than predictions. The postdiction advantage is thought to be a result of self-reflection and adjustment that occurs whilst completing the test (e.g. Glenberg and Epstein, 1987; Zabrucky, Lin and Moore, 2002).

The social cognitive theory emphasizes the relationship between cognitive, behavioural, environmental and personal factors and their interaction in terms of determining ones affect and motivation (Crothers, Hughes and Morine, 2008). Logically, it would be expected that the individuals who were informed of their genetic knowledge as feedback would re-evaluate their self-efficacy and confidence and adjust to the new self-evaluation information (Barling and Beattie, 1983). However, there are various reasons for their lack of subjective knowledge accuracy, which have wider implications for genetic education. Firstly, as described by Schunk and Zimmerman (1994), the ability to readjust one's self-efficacy in accordance with feedback requires a certain threshold of motivation or desire to achieve. Secondly, various self-evaluative processes must occur for successful readjustment of task-specific self-efficacy. For example, one should be a self-regulated learner who, in terms of a metacognitive process, will organise, self-monitor and self-evaluate at various intervals during learning acquisition (Pressley, Borkowski and Schneider, 1987). However, acquisition of learning in a relatively unfamiliar knowledge domain requires excessive cognitive resources, which in application to the current study's results may explain the high miscalibration scores. As undergraduates have on average a relatively low genetic knowledge (e.g. Bowling et al., 2008), answering genetic questions may require much cognitive resources, leaving fewer resources for metacognitive processes, and leading to greater miscalibration.

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Overall, the results of this study suggest that genetic literacy remains relatively low in student populations. This contributes to existing evidence, which suggests that the provision of improved genetic education is required at both the formal and informal educational level. This study found no significant relationship between types of media frame and reported genetic determinism. These results are, in a practical sense, encouraging as they suggest that peoples level of genetic determinism are robust against media framing. However, future research should investigate different framing formats in social media, particularly focusing on the varying social media audiences in terms of age, gender, income and educational level and/or background.

The relationship between genetic knowledge, genetic knowledge calibration and availability of feedback seems complex, and requires further investigation. The method of feedback adopted in this research (total answers correct) may have lacked enough detail for the participants to engage with, hence their genetic knowledge confidence score might not have been affected by their genetic knowledge score. This would explain why participants given feedback had higher miscalibration average than those not given feedback. Future research should investigate multiple forms of feedback with varying levels of detail to decipher the relationship between feedback and confidence in genetic knowledge.

The present study has identified that media framing had no effect on participants' reported views on genetics determinism. Whilst this may partially be a product of the limitations discussed above, it suggests that the views people hold on genetic essentialism are likely to be robust and not easily altered by media exposure. The feedback on Genetic Knowledge provided in this study seems to have done little to reduce knowledge miscalibration. Indeed, those participants that were asked to rate their genetic knowledge in the absence of feedback could do this more accurately than those who were provided with feedback on their performance. For future studies, especially in genetic knowledge, it appears that more detailed feedback may not only be more effective for knowledge calibration, but also less misleading. Both findings should contribute to the development of an open and productive discourse between genetic researchers and the general public so that genetic research findings can be used for the benefit of all.

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