



Conference on ‘Changing dietary behaviour: physiology through to practice’ Symposium 4: Changing diet and behaviour – putting theory into practice

Promoting healthy dietary behaviour through personalised nutrition: technology push or technology pull?

Barbara Stewart-Knox^{1*}, Audrey Rankin², Sharron Kuznesof³, Rui Poínhos⁴, Maria Daniel Vaz de Almeida⁴, Arnout Fischer⁵ and Lynn J. Frewer³

¹Division of Psychology, University of Bradford, West Yorkshire BD71DP, UK

²Northern Ireland Centre for Food and Health, University of Ulster, Coleraine BT521SA, UK

³Food and Society Group, Newcastle University, Newcastle-Upon-Tyne NE17RU, UK

⁴Faculty of Nutrition and Food Sciences, University of Porto, 4200-465 Porto, Portugal

⁵Marketing and Consumer Behaviour, Wageningen University, Wageningen 6706KN, The Netherlands

The notion of educating the public through generic healthy eating messages has pervaded dietary health promotion efforts over the years and continues to do so through various media, despite little evidence for any enduring impact upon eating behaviour. There is growing evidence, however, that tailored interventions such as those that could be delivered online can be effective in bringing about healthy dietary behaviour change. The present paper brings together evidence from qualitative and quantitative studies that have considered the public perspective of genomics, nutrigenomics and personalised nutrition, including those conducted as part of the EU-funded Food4Me project. Such studies have consistently indicated that although the public hold positive views about nutrigenomics and personalised nutrition, they have reservations about the service providers’ ability to ensure the secure handling of health data. Technological innovation has driven the concept of personalised nutrition forward and now a further technological leap is required to ensure the privacy of online service delivery systems and to protect data gathered in the process of designing personalised nutrition therapies.

Personalised nutrition: Nutrigenomics: Benefit: Risk: Information technology: Food4Me

What is personalised nutrition?

Internet and mobile phone technology has become integral to our daily activities and health and eating behaviour is no exception with recent technical advances having fuelled a drive towards direct-to-consumer (D-T-C) personalised nutrition. Personalised nutrition is an innovative concept that seeks to identify individual nutritional needs based on health status, genotype⁽¹⁾ and/or phenotype⁽²⁾ and then to provide healthy eating advice that is tailored to suit the individual (Food4me.org). Meanwhile, there is a growing body of evidence for the effectiveness of tailored feedback in bringing about

healthy behaviour change^(3–6). Surveys of D-T-C services have suggested that they are effective in producing healthy behaviour change in approximately one-third of users^(7–10). Awareness of D-T-C genetic tests is increasing among consumers⁽¹¹⁾. Those with a stake-hold in the delivery of personalised nutrition see immense potential to transform preventative and therapeutic nutrition and in doing so, to benefit public health and reduce health costs⁽¹²⁾. Personalised nutrition not only has potential for the tailoring of diet to individual health needs, but also to that of groups of people among the general public⁽¹³⁾. For personalised nutrition intervention to have any real and enduring impact upon public health,

Abbreviations: D-T-C, Direct-to-consumer.

***Corresponding author:** B. Stewart-Knox, email b.stewart-knox@bradford.ac.uk

however, we need to understand and take into account the public vision for such services⁽¹⁴⁾. Early D-T-C personalised nutrition initiatives have, on the whole, not been commercially successful. Despite the recent rapid advance in interactive health technology⁽¹²⁾ and the potential for societal benefit, there is a dearth of research in the area of personalised nutrition and nutrigenomics from the perspective of the general public^(15,16). Much of what research exists has focused on genetic testing albeit in various contexts, while fewer studies have considered personalised nutrition in particular.

What do the public think about nutrigenomics?

The future success of personalised nutrition in practice will depend upon the public being ready and able to take up aspects of the technology that are essential to service delivery. Personalised medicine and personalised nutrition share certain technologies. Genetic profiling is common to personalised medicine and nutrition and is likely to be important (along with phenotype, etc.) in informing personalised nutrition initiatives in the future. Understanding attitudes towards genetic testing, therefore, is relevant to understanding public response to nutrigenomics which represents the more 'medicalised' level of personalised nutrition provision.

Qualitative enquiry into societal views on genetic testing undertaken in the USA^(17–23), Australia⁽²⁴⁾, Switzerland⁽²⁵⁾, the Netherlands⁽²⁶⁾ and the UK⁽²⁷⁾, has indicated that people are aware of the potential benefits and hold generally positive attitudes towards genetic testing. Potential drivers of the uptake of genetic testing include own health^(17,18,24,28,29), the health of other family members and descendants^(17–19,24), for research purposes^(17,24,30) and curiosity^(10,18,24,25,28,30,31). All these studies, however, also catalogued concerns surrounding the enabling technology. Online privacy and the potential for information to be used by companies for commercial gain or to fall into the hands of insurers, employers or government agencies are among issues that have been consistently raised^(17–27,32,33). Aspects of the service delivery system itself may also need to be personalised. Whereas some studies of factors determining uptake of genetic testing^(23,34), have suggested that consumers liked the notion of autonomy and being in control⁽³³⁾, other works have implied that some consumers would prefer the input of a health professional^(32,35,36). In view of the differing perspectives, the mode of service delivery may need to be personalised.

Survey studies conducted in the USA^(8,37–47), Canada⁽⁴⁸⁾, Russia^(49,50), Finland^(51,52), Sweden⁽⁵³⁾, the Netherlands⁽⁵⁴⁾, Australia⁽⁵⁵⁾, Canada⁽⁵⁶⁾ and the UK⁽⁵⁷⁾ have indicated largely positive attitudes towards genetic testing. The public also appear positive about donating genetic material to biobanks^(19,58,59) and willing to supply genetic material for research purposes⁽⁶⁰⁾. Reasons suggested by the public for taking up genetic testing not only include improving one's own health^(61–64), but also of other family members and descendants^(62–66). Unsurprisingly, therefore, those with a

family history of inherited conditions have been found to have more favourable attitudes towards genetic testing^(21,55,67) and may be willing to pay more⁽⁵⁶⁾. A sizeable proportion would avail of genetic testing for no reason other than curiosity^(42,49,50,61,62,68). Others, on the other hand, may not want to know test results unless treatment was available^(53,54).

Despite generally positive attitudes towards genetic testing, and in keeping with existing qualitative studies into genetic testing (see previous paragraph), quantitative research, mainly surveys conducted over the last couple of decades conducted in the USA^(8,37,68–71), Canada^(48,56), Australia⁽⁷²⁾, Europe⁽⁷³⁾, the UK⁽⁵⁹⁾, Finland^(74,75) and the Netherlands⁽⁷⁶⁾ also indicate considerable concern among the public about internet privacy, data security, data use and data destiny^(41,43,44,51–56). Previous surveys into public attitudes towards genomics^(52,53,55,67), however, have failed to recruit samples that have been representative of the general population, making it difficult to draw firm conclusions as to the response of various societal groups to this emerging technology. Attitudes to genetic testing, however, appear to vary by gender, age and educational level. Males^(8,52,57,63) and older individuals^(11,37,52,57) appear most favourable towards the notion of genetic testing. Analyses of the impact of education level upon attitudes towards genetic testing have produced mixed results^(11,21,40,46,77–79). Those educated to a higher educational level^(21,78) and those in minority ethnic groups^(43,44) appear particularly concerned over data protection, use and destiny.

What does the public think about personalised nutrition?

Whereas personalised medicine relates genotypic information to propensity for disease, personalised nutrition relates genotypic information to optimal diet and health⁽⁸⁰⁾. Personalised nutrition also differs from nutrigenomics in taking a broader view of health and dietary health promotion and considering not only genotype, but also phenotype and lifestyle. This could render personalised nutrition less ethically sensitive and more amenable to public health promotion. However, consumer response to nutrigenomics and personalised nutrition remains an under researched area. Only a handful of qualitative (Morin⁽⁸¹⁾) and survey^(82,83) studies have considered the public perspective of nutrigenomics, all of which have indicated that between one-third and a one-half of those surveyed would be willing to avail such services and to follow a tailored diet. Having a health problem was also associated with being positive about receiving genetic-profiling information for the purpose of personalising their diet^(82,83). Research conducted in the Netherlands has indicated that consumers may be more amenable towards web-based personalised nutrition if they were in control of the use of the results⁽⁸⁴⁾. In keeping with this notion, other studies have implied that doubts about data security, data use and destiny would deter use of such services^(82,83).

The Food4Me project

The EU-funded Food4Me project appears to be the first of its kind to have adopted a mixed, qualitative and quantitative, survey design to gain an understanding of what would determine or deter uptake and compliance with personalised nutrition among the European general public and to establish the best way to deliver such services.

Focus group discussions were held in each of eight European countries (Spain, the UK, Ireland, the Netherlands, Poland, Portugal, Greece and Germany) during early 2012. Discussion was prompted using scenarios that depicted personalised nutrition at three successive levels of 'medicalisation' for which lifestyle, phenotypic and genetic information was collected (Food4me.org). The concept of personalised nutrition was viewed positively with potential to enhance health. Discourses arising in all eight countries framed personalised nutrition in terms of perceived benefit and risk⁽⁸⁵⁾. The sort of benefit expected from personalised nutrition were health related and similar to those which have been previously reported^(61–64) and included those related to health and fitness such as losing weight, building muscle, preventing and treating disease. D-T-C personalised nutrition services were likened to 'the food equivalent of a personal trainer'. Themes otherwise centred on the online delivery technology. The convenience of accessing dietary health services in the comfort of one's own home directly and not having to involve the general practitioner were also considered advantageous. The potential for anonymity afforded by such a system could serve to spare embarrassment and enable greater honesty in reporting dietary health behaviour.

Perceived risks were unrelated to personalised nutrition *per se* but rather to aspects of the delivery system itself such as those incurred by unwittingly visiting spurious websites or as a consequence of a lack of online security. Although in favour of personalised nutrition, the European public were unanimous across eight countries in expressing negative views on the ability of web-based enabling technology to ensure privacy and overcome issues surrounding data protection, usage and data destiny⁽⁸⁵⁾. As has been found in previous qualitative studies of genetic testing^(17–27,32,33) and nutrigenomics⁽⁸²⁾, issues surrounding data mishandling arose with concerns expressed about where information could end up. Possibilities discussed included the potential for commercial exploitation, for example, the selling of data to advertisers or spammers, as well as the more sinister possibility of surveillance purposes by insurers, employers and government agencies.

The next stage in the research process was to determine the distribution and generalisability of these ideas quantitatively. The prior qualitative research findings were used to inform the selection of items and validated scales and for inclusion in the Food4Me survey. The resultant questionnaire was translated and back-translated into the native languages of each of the nine EU countries (Germany, Greece, Ireland, Poland, Portugal, Spain, the Netherlands, the UK and Norway) involved

in the study. Members of the European public (n 9381) were quota sampled to be nationally representative for each country, on sex, age and education level and then surveyed online during February and March 2013. Similar to the previous surveys of public opinion of genetic testing^(41,43,44,51–56), the Food4Me survey found that perceived benefit was associated with intention to take up personalised nutrition. Statistical modelling suggested that the benefit attributed to personalised nutrition contributed to more favourable attitude towards and intention to adopt personalised nutrition⁽⁸⁶⁾. Perceived benefit was also associated with less perceived risk. Perceived risk was unrelated to intention to take up personalised nutrition. A possible explanation for this finding, and one suggested by the prior qualitative research, is that risk was not actually related to the concept of personalised nutrition but to the online delivery technology.

The Food4Me results, therefore, agree with those of previous studies that have investigated attitudes to genetic testing in suggesting that the public are acutely aware of the threat for data mishandling and misuse. Together, the qualitative and survey results suggest that to encourage uptake of personalised nutrition and enable people to achieve healthy dietary change, we must emphasise benefits while making the delivery system secure. Participants taking part in the initial qualitative studies were able to make suggestions as to how to minimise the damage should a privacy or data-handling mishap occur, for example, storing demographic, lifestyle and biological data separately. Nevertheless, the issue of how to ensure online privacy and protect and control data usage and destiny remains.

What does the future hold for personalised nutrition?

Previous research findings provide some clues as to why despite evidence that tailored interventions are effective in bringing about healthy behaviour change, early attempts to deliver personalised nutrition services on a commercial scale have failed. Expectancy value theories allow us to consider the implications of these findings for behaviour change. Protection motivation theory^(87–89) holds that the likelihood of a behaviour occurring, for example, taking up personalised nutrition, will depend upon the perceived size, severity and likelihood of any associated risk and perceived ability to reduce the risk. This implies a need for further consumer research to establish the perceived size, severity and likelihood of risk associated with online D-T-C personalised nutrition as well as perceived ability to reduce the risk and interaction with perceived benefit.

The overarching message from the research into the public response to genetic testing, nutrigenomics and personalised nutrition is that for D-T-C personalised nutrition to be taken up on a societal scale, people will need assurances that all online interactions would be private and that the provider will have ability to effectively handle and protect information collected in the endeavour to design personalised diets. In the wake of accidents

resulting in public data falling into the 'wrong' hands and recent revelations about how data generated through social media and other personal internet activities is used for marketing purposes and commercial gain, perceived weaknesses inherent in such technology are likely to limit the future development, consumer uptake and growth of such services.

Potential consumers, although positive about the concept of personalised nutrition, are telling us that in order for them to take up such services the information collected will require regulation⁽⁹⁰⁾. Control of the handling and use of health-related data will only be effective if the technology is in place to enable compliance with regulation⁽⁹¹⁾. Interdisciplinary research and innovation is needed urgently to render the delivery of health systems such as personalised nutrition secure and enable this potentially important public health innovation. Delivering personalised nutrition to the public will require working closely with information technologists in getting the delivery system perfected. Technological innovation has driven the concept of D-T-C health systems. The future of personalised nutrition would also appear to lie in the hands of information technologists. Meanwhile, promotion of personalised nutrition to the general public would do well to emphasise the (personal) benefits of personalised nutrition.

Acknowledgements

The authors would like to take this opportunity to acknowledge the work of the focus group moderators, observers and transcribers for their input into the qualitative study as well as GfK who undertook sampling and data collection.

Financial Support

The Food4Me project received funding from the European Union's Seventh Framework Programme for research, technological development and demonstration under grant agreement no. 265494.

Conflict of Interest

None.

Authorship

B. S.-K. drafted the manuscript and A. R. collected and reviewed the literature. All authors contributed to the design of the Food4Me studies and data collection. L. F. led the work.

References

1. Ronteltap A & van Trijp H (2007) Consumer acceptance of personalised nutrition. *Genes Nutr* **2**, 85–87.
2. Boland M (2008) Innovation in the food industry: personalised nutrition and mass customisation. *Innov-Manager Policy Pract* **10**, 53–60.
3. Gordon E, Griffin G, Wawak L *et al.* (2012) It's not like judgment day: public understanding of and reactions to personalized genomic risk information. *J Genet Couns* **21**, 423–432.
4. Webb TL, Joseph J, Yardley L *et al.* (2010) Using the internet to promote health behaviour change: a systematic review and meta-analysis, of the impact of theoretical basis, use of behaviour change techniques and mode of delivery on efficacy. *J Med Internet Res* **12**, e4.
5. Elder JP, Ayala GX, Slymen DJ *et al.* (2009) Evaluating psychosocial and behavioral mechanisms of change in a tailored communication intervention. *Health Educ Behav* **36**, 366–380.
6. de Bourdeaudhuij I & Brug J (2000) Tailoring dietary feedback to reduce fat intake: an intervention at the family level. *Health Educ Res* **15**, 449–462.
7. Egglestone C, Morris A & O'Brien A (2013) Effect of direct-to-consumer genetic tests on health behaviour and anxiety: a survey of consumers and potential consumers. *J Genet Couns* **22**, 565–575.
8. Haga SB, Barry WT, Mills R *et al.* (2013) Public knowledge of and attitudes toward genetics and genetic testing. *Genet Test Mol Bioma* **17**, 327–335.
9. Kaufman DJ, Bollinger JM, Dvoskin RL *et al.* (2012) Risky business: risk perception and the use of medical services among customers of DTC personal genetic testing. *J Genet Couns* **21**, 413–422.
10. O'Daniel JM, Haga SB & Willard HF (2010) Considerations for the impact of personal genome information: a study of genomic profiling among genetics and genomics professionals. *J Genet Couns* **19**, 387–401.
11. Finney Rutten LJ, Gollust SE, Naveed S *et al.* (2012) Increasing public awareness of direct-to-consumer genetic tests: health care access, internet use, and population density correlates. *J Cancer Epidemiol* **2012**, 309109.
12. Lewis KD & Burton-Freeman BM (2010) The role of innovation and technology in meeting individual nutritional needs. *J Nutr* **140**, 426S–436S.
13. Gibney MJ (2010) Personalised nutrition: diet, phenotype and genes. *J Nutrigenet Nutrigenomics* **3**, 58.
14. Onwezen MC, Reinders MJ, van der Lans IA *et al.* (2012) A cross-national consumer segmentation based on food benefits: the link with consumption situations and food perceptions. *Food Qual Prefer* **24**, 276–286.
15. Su HL & Lu TJ (2012) Exploring the consumer acceptance of and preferences in nutrigenomics-based personalized health management service. *Proc PICMET* **2012**, 3050–3058.
16. de Vrieze J, Bouwman L, Komduur R *et al.* (2009) Nutrition tailored to the individual? Not just yet – Realigning nutrigenomic science with contemporary society. *J Nutrigenet Nutrigenomics* **2**, 184–188.
17. Glenn BA, Chawla N & Bastani R (2012) Barriers to genetic testing for breast cancer risk among ethnic minority women: an exploratory study. *Ethnic Dis* **22**, 267–273.
18. Streicher SA, Sanderson SC, Jabs EW *et al.* (2011) Reasons for participating and genetic information needs among racially and ethnically diverse biobank participants: a focus group study. *J Commun Genet* **2**, 153–163.
19. Goldman RE, Kingdon C, Wasser J *et al.* (2008) Rhode Islanders' attitudes towards the development of a statewide genetic biobank. *Pers Med* **5**, 339–359.
20. Bates BR, Lynch JA, Bevan JL *et al.* (2005) Warranted concerns, warranted outlooks: a focus group study of

- public understanding of genetic research. *Soc Sci Med* **60**, 331–344.
21. Catz DS, Green NS, Tobin JN *et al.* (2005) Attitudes about genetics in underserved, culturally diverse populations. *Commun Genet* **8**, 161–172.
 22. Rose AL, Peters N, Shea JA *et al.* (2005) Attitudes and misconceptions about predictive genetic testing for cancer risk. *Commun Genet* **8**, 145–151.
 23. Doukas DJ, Fetters MD, Coyne JC *et al.* (2000) How men view genetic testing for prostate cancer risk: findings from focus groups. *Clin Genet* **58**, 169–176.
 24. Keogh L, McClaren B, Maskiell J *et al.* (2011) How do individuals decide whether to accept or decline an offer of genetic testing for colorectal cancer? *Hered Cancer Clin Pract* **9**, 17.
 25. Vayena E, Gourna E, Streuli J *et al.* (2012) Experiences of early users of direct-to-consumer genomics in Switzerland: an exploratory study. *Public Health Genomics* **15**, 352–362.
 26. Wijdenes-Pijl M, Dondorp WJ, Timmermans DRM *et al.* (2011) Lay perceptions of predictive testing for diabetes based on DNA test results versus family history assessment: a focus group study. *BMC Public Health* **11**, 535.
 27. Skirton H (2006) A legacy for the children – attitudes of older adults in the United Kingdom to genetic testing. *J Clin Nurs* **15**, 565–573.
 28. Hardie EA (2011) Australian community responses to the use of genetic testing for personalised health promotion. *Aust J Psychol* **63**, 119–129.
 29. McGowan ML, Fishman JR & Lambrix MA (2010) Personal genomics and individual identities: motivations and moral imperatives of early users. *New Genet Soc* **29**, 261–290.
 30. Su Y, Howard HC & Borry P (2011) Users' motivations to purchase direct-to-consumer genome-wide testing: an exploratory study of personal stories. *J Commun Genet* **2**, 135–146.
 31. Basson F, Futter MJ & Greenberg J (2007) Qualitative research methodology in the exploration of patients' perceptions of participating in a genetic research program. *Ophthalm Genet* **28**, 143–149.
 32. Wilde A, Meiser B, Mitchell PB *et al.* (2010) Public interest in predictive genetic testing, including direct-to-consumer testing, for susceptibility to major depression: preliminary findings. *Eur J Hum Genet* **18**, 47–51.
 33. Nyrhinen T, Leino-Kilpi H & Hietala M (2004) Ethical issues in the diagnostic genetic testing process. *New Genet Soc* **23**, 73–87.
 34. Townsend A, Adam S, Birch PH *et al.* (2012) "I want to know what's in Pandora's box": comparing stakeholder perspectives on incidental findings in clinical whole genomic sequencing. *Am J Med Genet* **158A**, 2519–2525.
 35. Rew L, Mackert M & Bonevac D (2010) Cool, but is it credible? Adolescents' and parents' approaches to genetic testing. *West J Nurs Res* **32**, 610–627.
 36. Frazier L, Calvin AO, Mudd GT *et al.* (2006) Understanding of genetics among older adults. *J Nurs Scholarsh* **38**, 126–132.
 37. Kerath SM, Klein G, Kern M *et al.* (2013) Beliefs and attitudes towards participating in genetic research – a population based cross-sectional study. *BMC Public Health* **13**, 114.
 38. Perez GK, Cruess DG, Cruess S *et al.* (2011) Attitudes toward direct-to-consumer advertisements and online genetic testing among high-risk women participating in a hereditary cancer clinic. *J Health Commun* **16**, 607–628.
 39. Falcone DC, Wood EM, Xie SX *et al.* (2011) Genetic testing and Parkinson disease: assessment of patient knowledge, attitudes, and interest. *J Genet Couns* **20**, 384–395.
 40. Hensley Alford S, McBride CM, Reid RJ *et al.* (2011) Participation in genetic testing research varies by social group. *Public Health Genomics* **14**, 85–93.
 41. McGuire AL, Diaz CM, Wang T *et al.* (2009) Social networkers' attitudes toward direct-to-consumer personal genome testing. *Am J Bioethics* **9**, 3–10.
 42. Hull SC, Sharp RR, Botkin JR *et al.* (2008) Patients' views on identifiability of samples and informed consent for genetic research. *Am J Bioethics* **8**, 62–70.
 43. Peters N, Rose R & Armstrong K (2004) The association between race and attitudes about predictive genetic testing. *Cancer Epidemiol Biomarkers Prev* **13**, 361–365.
 44. Singer E, Antonucci T & Hoewyk JV (2004) Racial and ethnic variations in knowledge and attitudes about genetic testing. *Genet Test* **8**, 31–44.
 45. Press NA, Yasui Y, Reynolds S *et al.* (2001) Women's interest in genetic testing for breast cancer susceptibility may be based on unrealistic expectations. *Am J Med Genet* **99**, 99–110.
 46. Donovan KA & Tucker DC (2000) Knowledge about genetic risk for breast cancer and perceptions of genetic testing in a sociodemographically diverse sample. *J Behav Med* **23**, 15–36.
 47. Durfy SJ, Bowen DJ, McTiernan A *et al.* (1999) Attitudes and interest in genetic testing for breast and ovarian cancer susceptibility in diverse groups of women in western Washington. *Cancer Epidemiol Biomarkers Prev* **8**, 369–375.
 48. Etchegary H, Cappelli M, Potter B *et al.* (2010) Attitude and knowledge about genetics and genetic testing. *Public Health Genomics* **13**, 80–88.
 49. Makeeva OA, Markova VV, Roses AD *et al.* (2010) An epidemiologic-based survey of public attitudes towards predictive genetic testing in Russia. *Pers Med* **7**, 291–300.
 50. Makeeva OA, Markova VV & Puzryev VP (2009) Public interest and expectations concerning commercial genotyping and genetic risk assessment. *Pers Med* **6**, 329–341.
 51. Toiviainen H, Jallinoja P, Aro AR *et al.* (2003) Medical and lay attitudes towards genetic screening and testing in Finland. *Eur J Hum Genet* **11**, 565–572.
 52. Aro AR, Hakonen A, Hietala M *et al.* (1997) Acceptance of genetic testing in a general population: age, education and gender differences. *Patient Educ Couns* **32**, 41–49.
 53. Hoeyer K, Olofsson BO, Mjörndal T *et al.* (2004) Informed consent and biobanks: a population-based study of attitudes towards tissue donation for genetic research. *Scand J Public Health* **32**, 224–229.
 54. Morren M, Rijken M, Baanders AN *et al.* (2007) Perceived genetic knowledge, attitudes towards genetic testing, and the relationship between these among patients with a chronic disease. *Patient Educ Couns* **65**, 197–204.
 55. Wilde A, Meiser B, Mitchell PB *et al.* (2011) Community interest in predictive genetic testing for susceptibility to major depressive disorder in a large national sample. *Psychol Med* **41**, 1605–1613.
 56. Ries NM, Hyde-Lay R & Caulfield T (2010) Willingness to pay for genetic testing: a study of attitudes in a Canadian population. *Public Health Genomics* **13**, 292–300.
 57. Sanderson S, Wardle J, Jarvis M *et al.* (2004) Public interest in genetic testing for susceptibility to heart disease and cancer: a population-based survey in the UK. *Prev Med* **39**, 458–464.



58. Brothers KB, Morrison DR & Clayton EW (2011) Two large-scale surveys on community attitudes toward an opt-out biobank. *Am J Med Genet A* **155A**, 2982–2990.
59. Treweek S, Doney A & Leiman D (2009) Public attitudes to the storage of blood left over from routine general practice tests and its use in research. *J Health Serv Res Pol* **14**, 13–19.
60. Pulley JM, Brace MM, Bernard GR *et al.* (2008) Attitudes and perceptions of patients towards methods of establishing a DNA biobank. *Cell Tissue Bank* **9**, 55–65.
61. Gollust SE, Gordon ES, Zayac C *et al.* (2012) Motivations and perceptions of early adopters of personalized genomics: perspectives from research participants. *Public Health Genomics* **15**, 22–30.
62. Akinleye I, Roberts JS, Royal CDM *et al.* (2011) Differences between African American and white research volunteers in their attitudes, beliefs and knowledge regarding genetic testing for Alzheimer's disease. *J Genet Couns* **20**, 650–659.
63. Cherkas LF, Harris JM, Levinson E *et al.* (2010) A survey of UK public interest in internet-based personal genome testing. *PLoS ONE* **5**, e13473.
64. Cappelli M, Surh L, Humphreys L *et al.* (1999) Psychological and social determinants of women's decisions to undergo genetic counseling and testing for breast cancer. *Clin Genet* **55**, 419–430.
65. Espfen M, Madlensky L, Aronson M *et al.* (2007) Colorectal cancer survivors undergoing genetic testing for hereditary non-polyposis colorectal cancer: motivational factors and psychosocial functioning. *Clin Genet* **72**, 394–401.
66. Bosomptra K, Flynn BS, Ashikaga T *et al.* (2000) Likelihood of undergoing genetic testing for cancer risk: a population-based study. *Prev Med* **30**, 155–166.
67. Kettis-Lindblad A, Ring L, Viberth E *et al.* (2005) Genetic research and donation of tissue samples to biobanks. What do potential sample donors in the Swedish general public think? *Eur J Public Health* **16**, 433–440.
68. Ormond KE, Hudgins L, Ladd JM *et al.* (2011) Medical and graduate students' attitudes toward personal genomics. *Genet Med* **13**, 400–408.
69. Horn EJ & Terry SF (2012) Consumer perceptions of genetic testing. *Genet Test Mol Biomarkers* **16**, 463–464.
70. Apse KA, Biesecker BB, Giardiello FM *et al.* (2004) Perceptions of genetic discrimination among at-risk relatives of colorectal cancer patients. *Genet Med* **6**, 510–516.
71. Neumann P, Hammitt J, Mueller C *et al.* (2001) Public attitudes about genetic testing for Alzheimer's disease. *Health Aff* **20**, 252–264.
72. Taylor S (2011) A population-based survey in Australia of men's and women's perceptions of genetic risk and predictive genetic testing and implications for primary care. *Public Health Genomics* **14**, 325–336.
73. Gaskell G, Allum N & Stares S (2003) Europeans and biotechnology in 2002, Eurobarometer 58-0 (pp. 44). <http://ec.europa.eu/publicopinion/archives/ebs/ebs177en.pdf>
74. Jallinoja P, Hakonen A, Aro AR *et al.* (1998) Attitudes towards genetic testing: analysis of contradictions. *Soc Sci Med* **46**, 1367–1374.
75. Hietala M, Hakonen A, Aro AR *et al.* (1995) Attitudes toward genetic testing among the general-population and relatives of patients with a severe genetic-disease – A survey from Finland. *Am J Hum Genet* **56**, 1493–1500.
76. Henneman L, Vermeulen E, van El CG *et al.* (2012) Public attitudes towards genetic testing revisited: comparing opinions between 2002 and 2010. *Eur J Hum Genet* **21**, 793–799.
77. Jonassaint CR, Santos ER, Glover CM *et al.* (2010) Regional differences in awareness and attitudes regarding genetic testing for disease risk and ancestry. *Hum Genet* **128**, 249–260.
78. Goddard KAB, Moore C, Ottman D *et al.* (2007) Awareness and use of direct-to-consumer nutrigenomic tests, United States, 2006. *Genet Med* **9**, 510–517.
79. Hughes C, Gomez-Caminero A, Benkendorf J *et al.* (1997) Ethnic differences in knowledge and attitudes about BRCA1 testing in women at increased risk. *Patient Educ Couns* **32**, 51–62.
80. Gibney MJ & Walsh MC (2013) The future direction of personalised nutrition: my diet, my phenotype, my genes. *P Nutr Soc* **72**, 219–225.
81. Morin K (2009) Knowledge and attitudes of Canadian consumers and health care professionals regarding nutritional genomics. *OMICS A J Integr Biol* **13**, 37–41.
82. Stewart-Knox BJ, Bunting BP, Gilpin S *et al.* (2009) Attitudes toward genetic testing and personalised nutrition in a representative sample of European consumers. *Br J Nutr* **101**, 982–989.
83. Roosen J, Bruhn M, Mecking R *et al.* (2008) Consumer demand for personalized nutrition and functional food. *Int J Vitam Nutr Res* **78**, 269–274.
84. Ronteltap A, van Trijp JCM & Renes RJ (2009) Consumer acceptance of nutrigenomics-based personalised nutrition. *Br J Nutr* **101**, 132–144.
85. Stewart-Knox B, Kuznesof S, Robinson J *et al.* (2013) Factors influencing European consumer uptake of personalised nutrition. Results of a qualitative analysis. *Appetite* **66**, 67–74.
86. Póinhos R, van der Lans IA, Rankin A *et al.* (in press) Psychological determinants of consumer acceptance of personalised nutrition in 9 European countries. *PLoS ONE* (In the Press).
87. Maddux JE, Rogers RW (1983) Protection motivation and self-efficacy: a revised theory of fear appeals and attitude change. *J Exp Soc Psychiatry* **19**, 469–479.
88. Rogers RW (1975) A protection motivation theory of fear appeals and attitude change 1. *J Psychol* **91**, 93–114.
89. Floyd DL, Prentice-Dunn S, Rogers RW (2000) A meta-analysis of research on protection motivation theory. *J Appl Soc Psychol* **30**, 407–429.
90. Ahlgren J, Nordgren A, Perrudin M *et al.* (2013) Consumers on the internet: ethical and legal aspects of commercialisation of personalized nutrition. *Genes Nutr* **8**, 349–355.
91. Bollinger JM, Green RC & Kaufman D (2013) Attitudes about regulation among direct-to-consumer genetic testing customers. *Genet Test Mol Bioma* **17**, 424–428.