The representation of the concept of heritability in Dutch written news media

Master Thesis (45 ECTS) of Science Education and Communication
Freudenthal Institute for Science and Mathematics Education, Utrecht University

Intention to publish in *International Journal of Science Education part B*

22 June, 2015

Author: A. (Anouk) Haverkamp, BSc. – Solis id: 3604675
Contact: anoukhaverkamp@hotmail.com

Supervisor: Dr. D.J. (Dirk Jan) Boerwinkel
Contact: d.j.boerwinkel@uu.nl

Abstract | A central question within biology is whether observed phenotypic variation in human health and disease is due to genes and/or environment and to what extent. More and more research results are published describing genetic components of human traits. Heritability is the parameter being used in this kind of research. Heritability describes the proportion of phenotypic variation of a certain trait that is due to genetic variation. The meaning of heritability is widely misunderstood. Misconceptions influence people's beliefs about the role of genes in the development of traits and subsequently affect people's preventive behavior. In order to eventually prevent these misconceptions, it is of importance to know how sources of genetics information represent the concept of heritability. For adults who finished formal education, media are the primary source of information about science and health-related issues. In this study, it was analyzed how Dutch written news media articles represent the concept of heritability and the concepts underlying its definition: genes, environment and variation. It was found that representations of concepts underlying heritability and of the concept of heritability itself are often too short-sighted or even lacking, hereby failing to establish a clear message on the meaning of heritability and possibly leading to misconceptions. This applies especially to news articles reporting on a scientific study. A more careful consideration of the representation of the concepts underlying heritability and the concept of heritability itself might improve the representation of heritability.

Table of Contents

Introduction

In this era of rapid scientific development, in which our society is becoming more demanding in the way it requires individuals to be able to cope with complex knowledge (Jennings, 2004), scientific literacy for all citizens has become the ultimate aim of science education (Jennings, 2004; Laugksch, 2000; Sadler, 2004). Scientific literacy refers to the ability to make informed decisions concerning socio-scientific issues (Sadler, 2004). In a democratic society, all citizens should be able to participate in societal discourses that involve science and be able to make personal informed decisions.

Due to an increased focus on genetic research[1] over the recent years, the pace of discoveries in genetics has accelerated (Lanie et al., 2004). This has led to applications of genetics that have consequences for science as well as for society (e.g. Boerwinkel & Waarlo, 2010; Boujemaa et al., 2010; Jennings, 2004; Lanie et al., 2004; Parrott et al., 2004; Williams, Montgomery, & Manokore, 2012). In the future, the focus on genes and genetics will increase even further (Lanie et al., 2004). As the public will be the (future) beneficiaries of genetic breakthroughs, it is important that citizens are genetically literate (Boujemaa et al., 2010; Emery, Kumar & Smith, 1998; Geller, Bernhardt, & Holzman, 2002; Lanie et al., 2004). Citizens should be able to understand information about genetics, to understand what this information means in their lives and to deliberate and debate about whether and how applications of genetics should be used. These skills are important on the level of democratic citizenship, as citizens have a voice in the development of goals and regulations concerning applications of genetics. Also, genetic literacy is important on the level of personal lives. Citizens have personal choices to make whether or not to use genetic applications (Boerwinkel & Waarlo, 2010), and genetics plays an increasingly important role in diagnostics and treatment of many diseases (Jennings, 2004).

In order to take full advantage of the advances in genetics, an understanding of basic genetic concepts such as *gene-environment interaction* is needed (Trumbo, 2000). More and more gene variants are being identified that are connected with physical and mental disorders and human behavior. This leads to discussions concerning how and to what extent this information might be useful in early recognition and/or treatment of these characteristics, and to what extent the environment may be of influence on the trait (Owen & McGuffin, 1997). Research concerning the interplay between genes and environment plays an important part in finding disease-related genes and in the epidemiology and treatment of many diseases. More and more research results are published describing genetic components of complex behavior.

Heritability is the parameter being used in this kind of research. Individual differences in traits (in this paper referred to as phenotypic or trait variation) may be due to genetic differences and/or environmental differences between individuals. Heritability describes the proportion of phenotypic variation of a certain trait that is due to genetic variation (e.g. Stoltenberg, 1997; Visscher, Hill, & Wray, 2008). Research shows that the concept of heritability is widely

[1] Genetic research studies genes and their role in inheritance. Genomic research looks at the entire genetic make-up of individuals. In this paper, 'genetic research' will refer to both genetic and genomic related research.

misunderstood and that this has consequences for peoples' ability to understand genetic research focusing on finding genes related to certain traits, and consequences for their ability to make informed decisions (e.g. Kaphingst, Lachance, & Condit, 2009; Marteau & Lerman, 2001; Parrott et al., 2004; Stoltenberg, 1997; Visscher et al., 2008). A first step in eliminating or preventing misconceptions about heritability and thus generating a better understanding of the concept of heritability among citizens, is to study the way the concept of heritability is communicated to the public.

This study therefore aims to describe how the concept of heritability is represented in written news media, as these are one of the most likely sources of information about genetics (Carver, 2013; Geller et al., 2002; Lanie et al., 2004; Trumbo, 2000). The results of this study may have implications for science education and communication developers and teachers.

Theoretical background

Introduction to the concept of heritability

A central question within biology is whether observed phenotypic variation in human health and disease is due to genes and/or environment and to what extent (Frazer, Murray, Schork, & Topol, 2009; Visscher et al., 2008). This knowledge not only contributes to fundamental biological principles, it is also of great value to our understanding of the development of diseases (Monaghan, 2008). Genome Wide Association (GWA-) studies are the most widely used approach to finding genes that are related to certain traits (Frazer et al., 2009). The parameter that is used in these studies, is that of heritability.

Heritability is about to what extent found differences in phenotypes can be attributed to differences in genotype and/or to differences in environmental factors (Stoltenberg, 1997; Visscher et al., 2008). Heritability was first applied in the fields of animal and plant breeding to predict whether a, and what kind of, program of selective breeding was likely be effective (Stoltenberg, 1997; Visscher et al., 2008). The first formal definition of heritability was given by J.L. Lush, an animal breeder: "The idea of heritability concerns whether the differences actually observed between individuals arose because they started life with different genotypes or were exposed to different environmental forces." (Lush, 1940, p.293). Nowadays, heritability is mainly used in studies concerning human characteristics, including behavior and disease. Heritability also plays an important part in fundamental biological research, providing new insights into the biology of the phenotype and into the nature versus nurture debate (Visscher, 2008).

A heritability estimate thus indicates what proportion of observed phenotypic variation in a certain population is due to genetic differences between individuals of that population. Heritability estimates range from 0,0 to 1,0 – 0,0 indicating no role of genetic variation in the observed phenotypic variation, 1,0 indicating that all observed phenotypic variation is due to genetic variation. The established value of heritability of a trait applies only to a particular population in a particular environment on a particular moment (e.g. Owen & McGuffin, 1997; Rice, 2008; Stoltenberg, 1997; Visscher et al., 2008). If it was found in a study that the heritability of IQ was 0,7, this means that 70% of the variation in IQ in the studied population is due to genetic differences, and the other 30% is due to environmental differences. In Appendix A, technical information on the calculation of heritability estimates can be found.

The following example, concerning the ability to run a fast time in marathons, clarifies the meaning of heritability. Environmental factors that can be of influence on running marathons, such as training, diet and running shoes are nowadays optimized for all professional runners. Differences in environment will therefore not cause much of the variation in the trait. Therefore, the heritability of being able to run a fast time in marathons is very high. This means that differences in genes cause most of the variation in this trait. This does not necessarily mean that genes are the most important in someone's ability to run a fast time in marathons. Also, the high heritability estimate does not mean that training is not important. In fact, when training was not yet optimized for all professional runners, heritability was lower, indicating that much of the variation in the trait was caused by environmental differences.

Problematic understanding of heritability

Lay definition of heritability

The meaning of heritability and what it implies is widely misunderstood. Before a technical definition of heritability was formulated, heritability was widely understood as 'the capability of being inherited' (Stoltenberg, 1997). This definition still predominates among lay people. In the English Oxford Dictionary, the term 'heritability' is defined as: "The quality of being heritable, or capable of being inherited" (English Oxford Dictionary online, 2014). This definition clearly does not take into account complex concepts about heredity (the role of genes, environment and interaction) and trait development. When confronted with the term heritability, lay people use its non-technical meaning to make sense of the text (Stoltenberg, 1997). Unfortunately, the non-technical definition of heritability is misleading when the technical definition is intended.

In The Netherlands, no common used distinct term for heritability exists (the term '*heritabiliteit*' exists, however, it is not being used in many instances). Heredity and heritability both translate into '*erfelijkheid'*. The word '*erfelijkheid*' is in the Dutch dictionary defined as: "Het verschijnsel dat lichamelijke of geestelijke eigenschappen van voorouders bij nakomelingen in meerdere of mindere mate worden teruggevonden" (Van Dale online, 2011) ("The phenomenon of finding physical or mental characteristics of parents in the offspring to a greater or lesser degree").

As heritability is considered to mean 'capability to be inherited', it is likely that misunderstandings about heredity and inheritance are transmitted to the concept of heritability. A number of studies have shown that students and citizens often have difficulties with understanding general genetic concepts (Boujemaa et al., 2010; Emery et al., 1998; Gericke, 2009; Lanie et al., 2004; Nehm & Reilly, 2007; Williams et al., 2012). These concepts include genes, environment and their roles in the development of traits, concepts that are indispensable in understanding heritability.

Problems with understanding of genetic concepts

The question '*what is inherited?'* lies at the heart of many misunderstandings within the field of genetics (Richards & Ponder, 1996; Stoltenberg, 1997). What actually is transmitted from parents to offspring seems to be a difficult feature to grasp for lay people. Lay people often express the notion that the traits themselves, carried by genes (Emery et al., 1998), are handed down from generation to generation (Stoltenberg, 1997). This can be seen in language use such as 'she has her mother's eyes' or 'it's in my genes'. Scientifically, the 'units of transmission' are only the genetic constituents of the sperm cell and the egg cell. Subsequently, traits are formed through development.

Lay people have trouble understanding the process of trait development. Lay people's conceptions of gene function show resemblance with the Mendelian model, which is the model that is often taught at secondary schools (Boujemaa et al., 2010; Trumbo, 2000). In the Mendelian model, the gene is regarded as a particle responsible for a certain physical trait, environmental factors not having any influence on the trait (Gericke & Hagberg, 2007). This model implies genetic determinism, in which genes are the only entities determining an individual's phenotype (e.g. Condit, 2007; Parrott et al., 2004). In fact, genes do not determine the phenotype, but a combination of and interaction between multiple genes and environment does. This means that the same genotype can give rise to different phenotypes.

As the Mendelian model, which does not explain gene function and trait development, is the predominant model of inheritance among students and citizens, and as the contribution of the environment on the outcome of certain traits is complicated, it is to be expected that lay people do not fully understand environmental influences on the phenotype. This has also been shown in different studies (e.g. Boujemaa, et al., 2010; Lanie et al., 2004; Tremblay & Gagné, 2001). Less obvious environmental constituents can easily be overlooked, like developmental circumstances in the womb and cellular and hormonal environments (Jiménez-Aleixandre, 2012). This is also the case for environmental influences on physical traits, like body height, weight and the likelihood of having a heart attack (Parrott, Silk, & Condit, 2003; Thomas, 2000). People often assign environmental factors a small role in contributing to physical traits, whilst most physical traits are in fact for a significant part determined by environmental factors.

Also, gene-environment interactions are mostly neglected by lay people. Genes and environment interact in different ways, having a joint effect on the development of traits (e.g. Boerwinkel & Waarlo, 2010; Frazer et al., 2009; Hunter, 2005). First, gene expression can be influenced by the environment. Second, environmentally induced changes in gene expression can be transmitted to offspring, which is called transgenerational epigenetic inheritance (Carver, 2013; Feil & Fraga, 2012; Jablonka & Raz, 2009; Monaghan, 2008). Third, the effect of an environmental factor may differ between people with different genetic make-ups (Hunter, 2005), like the stronger effect of sunlight exposure in people with lighter skins. In the study of Boujemaa et al. (2010) it was suggested that students did not refer to any gene-environment interaction due to the deterministic view of gene expression that prevails among most students. Trumbo (2000) also noted that genes and environment are often being taught as having separate effects on organisms and that interactions between the two are being ignored.

As genes, environment and their (interactive) role in the development of traits are essential concepts within heritability, the problems with understanding these concepts are likely to lead to problematic understanding of heritability. In particular simplistic ideas about genetic determinism and the lack of recognizing an important role for the environment in the development of traits cause the consequences of problematic understanding of the concept of heritability.

Consequences of problematic understanding of heritability

Misconceptions about genetic concepts and about heritability influence people's beliefs about the role of genes in diseases such as cancer. Research has suggested that people regard diseases with a genetic cause less controllable or preventable than they actually are (Kaphingst et al., 2009; Marteau & Lerman, 2001; Senior, Marteau, & Peters, 1999), because they believe that when genes play a role in getting the disease, the environment is of no or little influence. For example, in the study of Senior et al. (1999) it was found that the way people see the condition of having high cholesterol levels, depends on the way the cholesterol tests are perceived. People who perceived the test as detecting raised cholesterol, regarded the condition as controllable and less threatening. People who perceived the test as detecting a genetic problem, regarded the condition as uncontrollable. Another study led to the result that genetic testing for hypercholesterolemia did not affect the extent to which people feel they have control over the condition, but did affect their ideas about how and to what extent they could personally achieve this control (Marteau et al., 2004). For example, diet was regarded as less effective than medication among the people who knew about a genetic preposition for hypercholesterolemia.

Heritability beliefs may also influence people's choices about family planning. If one of the parents has a disease of which a high heritability is known from a study, parents might estimate the chance of having children with the same disease higher than it actually is and base their family planning choices on wrong information. In a study about the influence of the perception of inflammatory bowel disease on family planning decisions was found that 15% of the patients made (free-text) comments about their worries about the genetic risk of their children getting the disease, because the disease had a partial genetic component (Mountifield, Bampton, Prosser, Muller, & Andrews, 2009). However, Mountifield et al. describe this should not be a reason to decide against having children, as the family history is not sufficient to predict the development of the disease in the offspring. In a study that focused on families with a history of cystic fibrosis was found that 53% of the subjects overestimated the chance of having a child with the disease (Lafayette, Abuelo, Passero, & Tantravahi, 1999).

Beliefs about heritability also influence the way people think about personal accountability for traits like IQ and behavioral traits. An example of a consequence of genetic determinism was seen in 2009, when a convicted murderer's jail sentence was cut because he had genes associated with aggressive behavior (Feresin, 2009).

Known misconceptions concerning heritability

From previous studies, a number of specific misconceptions concerning heritability were identified and listed in Box 1. Especially the first five misconceptions are related to problems with understanding genes, environment and the development of traits and these are the ones that thus are most likely to be involved with the consequences of misunderstanding heritability.

Box 1 | Misconceptions about heritability derived from scientific literature

1. *Heritability estimates indicate what proportion of a trait is passed on to the next generation* (Visscher et al., 2008). This misconception implies that the heritability estimate indicates to what extent traits are passed on. This is not correct, as traits are not inherited, but genes. Also, heritability estimates do not provide information about to what extent something is passed on, but provide information about variation of a trait in a population.

2. *Heritability estimates indicate causal roles of genes and environment on the trait on the individual level* (Stoltenberg, 1997; Visscher et al., 2008). This misconception implies that heritability estimates provide information about to what extent genes and environment are of importance in the development of a trait. This is not correct, as the heritability parameter is a feature of a studied population and cannot be used to explain individual traits.

3. *High heritability indicates genetic determination* (Owen & McGuffin, 1997; Visscher et al., 2008). This misconception implies that high heritability means that genetic factors are the only important factors in the development of a trait. This is not correct, as high heritability means that much of the observed phenotypic variation in a trait is caused by variation in genotypes. The environment can still be of importance in the development of the trait, so people can influence the development of traits.

4. *Heritability is a fixed property of a trait* (Owen & McGuffin, 1997). This misconception implies that each trait has its own heritability. This is not correct, as heritability estimates of the same trait may differ between populations and can also change in one population. Heritability is a feature of the studied population and not of a trait.

5. *Heritability estimates explain the proportion of disease cases that are attributable to genetic or environmental factors* (Vineis & Pearce, 2011). This misconception implies that a heritability estimate refers to the proportion of disease cases caused by genetic factors. This is incorrect, because heritability estimates are about variation and cannot be used to compute the proportion of disease cases that are attributable to genetic or environmental factors.

6. *Low heritability indicates that genes play little part in the development of a trait* (Visscher et al., 2008). This misconception implies that low heritability means that genes are not of great importance in the development of traits (this is a conversion of misconception 3). This is incorrect, because low heritability indicates that a small portion of variance in the trait is caused by variation in genotypes. Genetic factors that do not differ much between people can still be very important in the development of a trait.

7. *Low heritability indicates no genetic variation* (Visscher et al., 2008). This misconception implies that low heritability means that there is no genetic variation. This is incorrect, because low heritability means that a small proportion of trait variance is due to genetic variances. This does not have to mean that the genetic variation is small, only that genetic variation does not cause much of the phenotypic variation.

8. *Heritability is informative about the nature of between-group differences or shifts in phenotypes over time* (Visscher et al., 2008). This misconception implies that differences between populations or between different time points are caused by genetic factors. This is incorrect, as a heritability estimate is specific for the measured population in a certain environment on a certain moment. Differences in the environment between groups or between time points may cause trait variation as well.

9. *Large heritability implies genes of large effect* (Visscher et al., 2008). This misconception implies that heritability is informative about whether a trait is controlled by many genes of small effect or by few genes of large effect. This is incorrect. A large heritability implies strong correlation between phenotype and genotype. This way, loci (specific places on chromosomes) with an effect on the trait can be more easily detected. This does not mean that there is only one gene that affects the trait.

Misconception 2 and 3 can be related to people applying heritability on their individual level, thinking that the heritability estimate indicates that genes cause a trait. Hereby, these misconceptions could affect their health-related behavior. The fourth misconception may contribute to the idea that this is fixed and valid for every individual. The first misconception is likely to reinforce the third misconception, as indifference to gene function (DNA, proteins, molecules etc.) might enhance deterministic thinking. It was found that if people consider genes and traits to be the same, they ignore the mechanisms of gene expression and trait development (Gericke, 2009). The fifth misconception may lead to people thinking that a disease can be determined either fully by genes or by the environment, an either-or view that was also found in the study of Tremblay & Gagne (2001). This either-or view prevents people from understanding the basics of trait development in which genes and environment and their interactions are of great importance.

The sixth misconception is the reverse of the genetic determinism misconception, this time low heritability indicating 'no role for genes in the development of traits', instead of high heritability indicating 'no role for the environment'. Even though there are no indications of this misconception possibly to be conveyed by written news media (discussed in the following section), still it might be possible that this misconception is transferred to lay people via these media and that the reinforcement of this misconception reinforces genetic determinism (because when people think low heritability indicates 'no role for genes', they will probably think that high heritability indicates 'no role for the environment'). The remaining three misconceptions are more detailed on the subject of heritability and will probably only occur if one knows what heritability entails.

In order to eventually prevent these misconceptions, it is of importance to know how media represent the concept of heritability.

The status of genetics information in written news media

Secondary school biology education is often the only formal learning environment in which students receive information on genetics (Lanie et al., 2004). However, most students only receive a general biology course in which genetics is one of many subjects (Trumbo, 2000) and many citizens lack a formal science education that includes recent insights in genetics and genetics education (Lanie et al., 2004). After formal education, publicized stories in the media are the primary source of information about science and health-related issues (Geller et al., 2002; Lanie et al., 2004). This is even the case for scientists and physicians (Carver, 2013; Geller et al., 2002; Holzman et al., 2005). People are dependent on the media for the latest information about developments in the field of genetics. In this section, it will be discussed what is already known from previous studies about the representation of genes, environment and heritability in written news media.

The public wants to know about developments in the genetic field that affect them - like what treatments are available for their specific genetic make-up and for what traits they can screen their unborn baby (Carver, 2013). It is therefore not surprising that the media have covered genetics widely in the last three decades (Carver, 2013; Geller et al., 2002; Holzman et al., 2005). Frazer et al (2009) state that in a two-year period (from April 2007 until the beginning of 2009), over 220 stories were publicized in the media that reported results of GWA-studies, linking genes to almost all disease categories: “Almost all disease categories have been addressed, including cardiovascular, neurodegenerative, neuropsychiatric, metabolic, autoimmune and musculoskeletal diseases, and several types of cancer.” (Frazer et al., 2009, p.244).

By organizing and presenting information in ways that convey a specific meaning to the public (also called framing), the media can shape the public’s perception and understanding of genetics (Carver, 2013; Petersen, 2001). However, this is not being done in a simple or direct way. As stated by Petersen (2001), research has shown that people’s responses to news reports about genetics are likely to be more complex and diverse than what would be expected if the media and public discouse were directly linked. The impact of framing in the media depends, among other factors, on prior knowledge and experience of the public. However, it is likely that media stories on genetics find a receptive audience, as they are the primary source of information about genetics and conveyed in such a way that they appeal to the public.

The way journalists frame messages depends on various internal and external factors (Carver, 2013). Journalists have multiple interests to take into account when writing an article. Often, they are paid primarily to attract the interest and attention of many people (Condit, 2007). This leads to the need to ‘hype’ the article. Journalists often do so by framing science as “offering wonders and miracles” (Condit, 2007, p.815). Also, journalists may be pressured to reflect the concerns of the scientific community (Petersen, 2001). Genetic researchers are keen to use the media to promote their scientific work and the public image of genetics and genomics. Both interests may lead to an exaggerated positive image of genetics in the media. General consensus exists that media stories portray genetics as ‘the final explanation’ and genes as all powerful (e.g. Carver, 2013; Condit, 2007; Jiménez-Aleixandre, 2012; Petersen, 2001). The frames ‘gene optimism’ (Carver, 2013) and ‘genes win!’ (Condit, 2007) are used to communicate the impressions that genes are the most important factor underlying disease, that genetic discoveries triumph over environment and that science, by finding these genes, will lead to prevention and treatment (Carver, 2013; Condit, 2007; Jiménez-Aleixandre, 2012; Petersen, 2001). These impressions reinforce genetic determinism.

Trumbo (2000) argues that “Too often media reports seem to resemble a genetic scoreboard rather than a discussion of how genetics and environments influence traits.” (p.259). Studies have indicated that media reports rarely mention the influence of environmental factors and the interaction of multiple genes and the environment on the development of a disease (Carver, 2013; Petersen, 2001). Even when study results indicate gene-environment interaction, media reports hold genes responsible for the disease (Condit, 2007; Horwitz, 2005). If environmental influences are mentioned, this is often only in passing or at the end of the article (Carver, 2013). Furthermore, media articles characterize the environment only through factors people can identify with (Horwitz, 2005). Apparently, more complex environmental mechanisms are often left out.

The public welcomes the deterministic message in the media, as it removes the personal blame of the environment and behavior for disease. However, these messages convey overly simplified information about genetics that can mislead the public (Carver, 2013). Journalists often use a Mendelian way of framing the gene and often use the words 'a gene for …' (Condit, 2007). There are indications that a significant percentage of lay people believes that 'a gene for a disease' means that the affected person will absolutely get the disease. Genetic determinism in the media may lead to people overestimating the importance of genes in their lives and overlooking the importance of changing environmental conditions that predisopes to disease (Carver, 2013; Petersen, 2001).

Media reports that convey the 'genes win!' or 'genetic optimism' frame, might misreprent heritability studies as though heritability would be a measure of the degree to which genes triumph over the environment (Condit, 2007). While framing of the gene concept in the media is extensively studied, there are no known analyses of how the concept of heritability is portrayed in the media, and whether this concept is communicated in Dutch media at all.

Research aim and question

This study aims to describe how the concept of heritability is represented in Dutch written news media, as these are, besides biology education, the most likely sources of genetics information and because there are indications that the representation of the concept of heritability in written news media might be problematic. This study does not focus on a specific target group but aims to provide an insight into the representation of heritability in an important source of genetics information. The analysis of texts about heritability will lead a description of how the concept of heritability and its underlying concepts are represented, and whether this might be at risk to convey misconceptions.

Results of this study might be used by developers of genetic education and communication materials, in the form of recommendations that addresses which expressions about heritability and underlying concepts should be avoided and which expressions are indispensable to convey a correct meaning of heritability. Furthermore, knowledge about what students read about heritability and what might be problematic, will provide teachers with more insight about what they should take into account when teaching about heritability. Last, this research may add to the general knowledge base of genetic literacy and provide insight in how scientists, science educators and science communicators may more effectively deal with terms that have scientific as well as lay meanings.

The research aim generates the following research question of this study:

How is the concept of heritability represented in Dutch written news media?

Material and method

This study is a descriptive study with qualitative data obtained from written news media. The used research method was text analysis. A tool was developed for the analysis of written news media articles that communicate the concept of heritability.

Development of the analysis tool

As this research was the first to study the communication of the concept of heritability, a new method for analysis was developed. Several theories and guidelines about text analysis have been considered in this process.

Text analysis can be executed using both quantitative and qualitative research methods, or a combination of these. In order to understand meanings and possible effects of texts, which is the aim of this study, in-depth text analysis is required (Macnamara, 2003). The methodology that can best be used for qualitative text analysis is poorly defined and specific guidelines are lacking. However, Mayring (2000) (as cited in Macnamara, 2003) provides two procedures for qualitative text analysis: inductive category development and deductive category application. Inductive category development implies working from specific observations of categories and patterns towards a broader theory. Deductive analysis involves applying this broad theory to specific observations. Qualitative text analysis is thus characterized by the design of categories which are later used in the analysis of texts (instead of creating categories as the researcher goes along) (Macnamara, 2003). Making use of pre-determined categories increases the systematicity of qualitative analysis. This method is often being used by studies that focus on media analysis (e.g. Carver, 2013; Matthes & Kohring, 2008).

Therefore, as a starting point of the analysis of how the concept of heritability is being represented, first a set of preliminary categories and subcategories for analysis was developed based on the theoretical background. This is in line with the media content analysis flowchart of Macnamara (2003, pp. 19-20), in which it is described that the first step of media analysis is to perform theoretical research in order to identify the content that is important to analyze. From the theoretical basis, it is known what constitutes the definition of heritability and thus what the crucial concepts are that should be communicated to convey a correct meaning of heritability. Furthermore, aspects of these concepts that are part of existing misconceptions or could lead to misconceptions were identified.

The second step in qualitative media content analysis is to screen some examples of the content that will be analyzed (Macnamara, 2003). This serves to find additional categories or subcategories and to define how these categories will be conceptualized. Therefore, an in-depth analysis of a news article, reporting on a heritability study and discussing the results extensively, was performed to find additional categories and subcategories. The following categories were regarded as categories that provide information about how the concept of heritability is represented:

- Message:
  - Message in the title;
  - Main message of the article;
  - Comparison of the main message to the scientific study results (if applicable);
- Concepts underlying heritability
  - Genes: whether the development of the trait is attributed to one or to multiple genes, how the concept of gene is described, whether possible links between genes and phenotype are described, and whether genetic deterministic language is present;
  - Environment: whether the environment is mentioned and to what extent, where environment is mentioned, what environmental factors are mentioned and with what words the environment is addressed;
  - The roles of genetic and environmental factors in the development of traits: whether the article assigns influences on the development of traits to genes and/or to environmental factors and (if applicable) what kind of interaction is mentioned;
  - Variation: whether genotypic, environmental and trait variation are mentioned.
- Heritability:
  - Language used to refer to heritability;
  - Meaning of heritability: whether the meaning of heritability is explicated, whether it is described how heritability estimates can be found and whether scientific aspects of heritability are mentioned;
- Misconceptions.

The third step in media content analysis is to create a preliminary or *a priori* coding scheme describing all measures (Macnamara, 2003). This was done by analyzing two news articles with the use of the categories. This provided information about how each category could be measured. For each category, this resulted in a defined number of multiple choice questions and/or open-ended questions. Original evidence in the form of quotations could be added to categories for which this was relevant, in order to elucidate the relation between interpretation and evidence. The tool for analysis in its final form can be found in Appendix B.

Other tools for analysis might have been developed to analyze the communication of heritability, however, in this case a tool was developed that allows an assessment on whether an article might stimulate or inhibit the risk of communicating misconceptions, based on extensive literature study and example analyses. The tool for analysis described above is therefore most valid for this study.

Material

The next step in media content analysis is sampling (Macnamara, 2003). As already apparent, news media constitute an important source of genetics information for the public. Only written media have been analyzed in this study, as written texts are better accessible (especially newspaper articles, which are archived in computer databases) than for example broadcast news or informational videos (Crawley, 2007).

Newspapers and news websites reached 93% of Dutch citizens of age 13 and older in 2013 (Nationaal Onderzoek Multimedia (NOM), 2013). Media reports concerning science do not differ substantially in content between regional and national newspapers (Evans, Krippendorf, Yoon, Posluszy, & Thomas, 1990). National newspapers have a larger reach than regional newspapers (per newspaper title). Therefore, and for practical considerations, only articles that have been published in national newspapers have been included in this study.

More and more people read news in free newspapers and via news websites or smartphone applications (NPD Nieuwsmedia, 2013), so besides printed news media, the most used digital news sources have been included. These are NU.nl and NOS.nl, used by respectively 46,9% and 39,4% of the respondents of the monthly survey Dutch Digital Media Measurement (Verenigde Internet Exploitanten, Platform media-adviesbureaus, & GfK, 2014). This set of sources is expected to be representative of the news articles that are accessible to the public on a daily basis.

The online newspaper archive LexisNexis has been used to find articles for analysis. Keywords that were likely to occur in articles discussing heritability (and were likely to yield a selection of articles of which a relatively large percentage was relevant) were determined. These were: '*gen' ('gene'), 'genen' ('genes'), 'erfelijk' ('hereditary'), 'erfelijkheid' ('heredity'/'heritability*[2]*)* and '*genetisch bepaald' ('genetically determined')*. All of the keywords yielded unique relevant articles. From the resulting list of articles, only news reports that discussed the results of a heritability study or discussed the heritability of a certain trait as the main subject, were included in this study.

As this research is based on a qualitative method, the sample is not necessarily required to be random or representative (Macnamara, 2003). The sample should comprise examples that are typical or representative for most news articles, examples that are disconfirming and examples that are exceptional (Miles and Hubermann, 1994 (as cited in Macnamara, 2003)). By using a combination of all three examples, qualitative analysis can explore the whole range of possible ways of representation of the concept of heritability (Macnamara, 2003; Mays & Pope, 1995). Articles were selected from the year 2014. The sample comprised typical, disconfirming and exceptional articles and was also representative for what information about heritability is accessible for the public via written news media, as all found articles were analyzed. In Appendix C an overview of the used articles and the corresponding codes can be found. All articles were coded using the letters NA (news articles) and a number. Some numbers are missing as these corresponded to articles which were selected, but discarded after careful reading because they did not satisfy the selection criteria.

Procedure

During the process of data collection, the analysis tool was continually under development, as the analysis of new texts provided the rater with new insights. This is a recognized merit of using a qualitative approach (Hertog & McLeod, 2003; Pope & Mays, 2000). A researcher

[2] Remember that 'erfelijkheid' translates into both 'heredity' and 'heritability'

should not be constrained by trying to fit the findings into the existing options. If a category within the tool for analysis was adjusted, this adjustment was also carried out in the text analyses that were already conducted.

A manual for analysis was created, describing each category, explaining how they should be analyzed and providing examples. The manual was created after the analysis of five texts, in order for the manual to be complete and explicit. Together with the systematic tool for analysis, a manual improves the reproducibility and consistency of the analyses and enables another researcher to analyze the data in the same way. The manual thus prevents the often heard criticism about qualitative research that it is so personal to the researcher that other researchers will not be able to come to the same conclusions (Mays & Pope, 1995). The manual also ensured that all texts were analyzed using the same 'rules', ensuring consistency of the method. The consistency and reproducibility of the analyses are measures of the reliability.

The reliability of the method of analysis can be determined by having another skilled researcher independently perform an analysis and comparing agreement (Mays & Pope, 1995). There is no consensus about the suitability of interrater reliability in qualitative research methods (Pope & Mays, 2000). However, Pope and Mays (2000) state that there might be advantages of determining reliability by using more than one researcher and Macnamara (2003) notes that interrater reliability should be used, but with more flexible measures. The reliability of the method of this study was determined by using two knowledgeable researchers on the topic of genetics. Two articles were analyzed by the first rater and by the two researchers. A discussion about the agreement of their answers revealed that differences in the analyses between the raters were caused by different interpretations of the questions/categories in the analysis tool rather than different interpretations of the articles. The questions were thus sharpened and the way in which these questions should be answered was described in more detail in the manual. Agreement was reached about what indications in the text should lead to what answers.

Data analysis

A descriptive account of the data will be given. Explanatory quotations from the texts and answers on other categories/subcategories will serve to exemplify what factors underlie a certain answer in all categories. Relevant correlations between categories or between categories and article properties will be described. Where possible and helpful, results will be represented in charts. The way in which the results are shown differs for different categories of analysis. In case of multiple choice answers, the number of texts in which a certain answer has been given will be determined. In case of the open-ended question '*What environmental factors are mentioned / with what words is the environment addressed?*', it will be described what types of environmental factors were mentioned and in how many cases. Further, it will be described in what part of the texts the environment is mentioned, how many times it is mentioned and with what words. For the questions concerning genetic deterministic language and the words or sentences that are being used to refer to heritability, it will be represented in tables in what number of texts each similar word or sentence was used.

Results

A total of 24 articles was analyzed. The results will be described for each category of analysis. In the discussion section, the findings will be connected to the discussed misconceptions.

Message

Environmental influence/factors tend to be left out of titles

In almost half of the articles, the message in the title did not correspond to the main message that was communicated in the article. This was mostly due to the fact that the title contained genetic deterministic language while the language in the article was more reserved. Only in one title (NA32), the role of multiple factors in the development of a trait became clear: "*Genen en omgeving net zo belangrijk bij ontstaan autisme" ("Genes and environment equally important in the development of autism").* A few other titles (NA34, NA5) do represent a role for genes as well for the environment, but it is doubtful whether this is understood by the public. It was found that most titles suggested a causal relationship between genes and the trait, even if the article merely mentioned a *link* between genes and the trait, and not a causal relationship (NA28, NA36, NA2). Only one title (NA29) was found that explicitly noted a correlation between the gene and the trait, rather than a causal relationship that might have more impact to the readers: *'Twee genen gelinkt aan gewelddadig gedrag" ("Two genes linked to violent behavior.").*

In half of the articles reporting on a scientific study, results were incorrectly described

Thirteen articles were found that reported on a recently published scientific study about the heritability of a certain trait. All of the online news articles were found in this category. In eleven cases, the corresponding scientific articles were found. In five articles, the main message differed from the study results. Several reasons were identified. First, genetic deterministic messages found in the article not corresponding to the research (NA5, NA27, NA36); second, the article suggesting a causal relationship, while this was not mentioned in the scientific article (NA5, NA27); third, a wrong interpretation of the study results (NA33, NA34). For example, in a scientific study was found that the abundances of specific bacterial populations were partly determined by genes. In the news article (NA34), it was described, however, that the presence of specific bacterial populations is completely caused by the genes.

Concepts underlying heritability

In most articles, traits were attributed to multiple genes

All but one articles attributed the discussed trait to more than one gene. In a small portion of articles (NA1, NA4, NA12, NA13, NA26) it was explicitly communicated that many genes account for a trait (with the exception of NA13, which reported on a scientific study, all of these articles discussed more in general the heritability of a certain trait), for example:

> *"Waarschijnlijk zijn er honderden genen die onafhankelijk van elkaar een stukje bijdragen aan de stoornis."* (NA14)
> *"There are probably hundreds of genes that all have a small contribution to the disorder".*

In most (thirteen) articles, the fact that multiple genes are responsible for a trait was communicated only implicitly by using plural words like '*genen*' *('genes')* instead of '*gen*' *('gene')*. The articles that reported on a scientific study, mostly held only one or a few genes responsible for the trait, for example:

> "*Er waren twee genvarianten bekend die meer voorkomen bij koffiedrinkers (…). In het nieuwe onderzoek zijn er nog twee genen in dezelfde categorie ontdekt.*" (NA5)
> *"Higher occurrences of two gene variants were known with coffee drinkers (…). In this new research, two genes of the same category were found."*

Genes were mostly described as units of transmission, influencing a trait

In about half of the articles, the way in which the gene influences the phenotype was in some way described. In most cases, the effect of the genes was explained on the level of tissue/organ function. Hereby, the effect of the gene on the phenotype was explained by discussing how the gene(s) affects other phenotypes that are related to the discussed phenotype. For example, the effect of genes on arithmetics and reading skills was explained by discussing the effect of genes on the phenotype of certain brain functions:

> *"Waarschijnlijk beïnvloeden deze genen bepaalde hersenfuncties die bij zowel lezen als rekenen van pas komen."* (NA33)
> *"These genes probably have influence on certain brain functions that are used with arithmetics as well as with reading."*

By explaining the function of the gene, articles clarify that the way from genes toward the trait contains multiple steps. Also, words like '*samenhangt met*' *('associated with')*, '*beïnvloedt*' *('influences')*, '*een rol spelen bij*' *('play a role in)*, deny that genes 'contain' traits or are the actual traits in miniature. In most articles, genes were thus described as units of transmission *influencing* the trait, which is the correct conception of genes.

In nine cases, the language used seemed to describe the gene (also) as a carrier of the phenotype or as the phenotype itself, which is an incorrect conceptions of genes. Three different indications were found. First, naming the gene after the trait, for example: *"Autismegenen"* (NA8) *("autism genes")* . Second, using 'gene for…' language, for example: "*Een gen voor oud worden"* (NA26) *("A gene for reaching old age")*. Third, stating that a trait is present in the genes, for example: "*Succes zit in de genen"* (NA25) *("Success lies in the genes")*. In three articles no clear indications were found of how the concept of gene was described.

Most articles contained genetic deterministic language

In most (fourteen) articles, genetic deterministic language was present. In three of these (NA16, NA28, NA25), the only indication for genetic determinism was present in the title. In Table 1, the found types of genetic deterministic language are displayed.

Table 1

Categories of genetic deterministic language and the number of articles in which they were found

Categories and examples	Number of articles
Genes determine the trait *"Goede genen maken iemand tot een goede verkoper."* (NA6) (*"Good genes make someone a good salesman"*)	4
Genes are responsible for the trait *"…proberen we er nu achter te komen welke specifieke genen verantwoordelijk zijn voor het geluksgevoel"* (NA24) *("We now try to find out what specific genes are responsible for feeling happy")*	3
Genes called after the trait *"Autismegenen."* (NA8) *("Autism genes")*	3
The trait lies in the genes *"Succes zit in de genen"* (NA25) *("Success lies in the genes")*	3
Gene 'for' a trait *"Gen voor oud worden"* (NA26) *("A gene for reaching old age")*	2
Genes cause the trait *"Koffieleut? Komt door je genen (…)."* (NA5) *("Coffee drinker? Caused by your genes (…)")*	1
The notion that one cannot influence the trait (because of genes) *"Brak? Niet je eigen schuld"* (NA27) *("Hangover? Not your own fault")*	1
The trait can be determined by looking at the genes *"Er is nu zelfs een DNA-test die mensen helpt hun commerciële talenten te ontdekken."* (NA6) *("There is even a DNA test that helps people discover their commercial talents")*	1

In eight articles, no indications of genetic determinism were found. Four of these articles explicitly discouraged genetic determinism. In three other cases, it was found that though genetic determinism was explicitly discouraged, still indications of genetic determinism were present. The ways in which genetic determinism was discouraged can be divided in two types. The first type is the notion that people can influence the effect of the genes by their behavior. The second type is the notion that a gene does not determine a trait by itself, for example:

> *"Hoofdonderzoeker Jari Tiihonen benadrukt wel dat de twee genen zeker niet allesbepalend zijn bij gewelddadig gedrag (…). Factoren als omgeving en opvoeding zijn waarschijnlijk veel bepalender bij de vraag of iemand gewelddadig gedrag zal vertonen of niet."* (NA29)
> *"Lead researcher Jari Tiihonen emphasizes that these two genes are not the only determining factors for violent behavior (…). Factors like environment and upbringing probably contribute more to whether someone will show violent behavior or not."*

The role of the environment was more extensively discussed in articles that discussed the heritability of a trait as the main subject than in articles reporting on a scientific study

In Figure 1 it can be found whether an article mentioned the environment or not. Differences were found between articles that discuss more in general the heritability of a trait, and articles that reported on a scientific study.

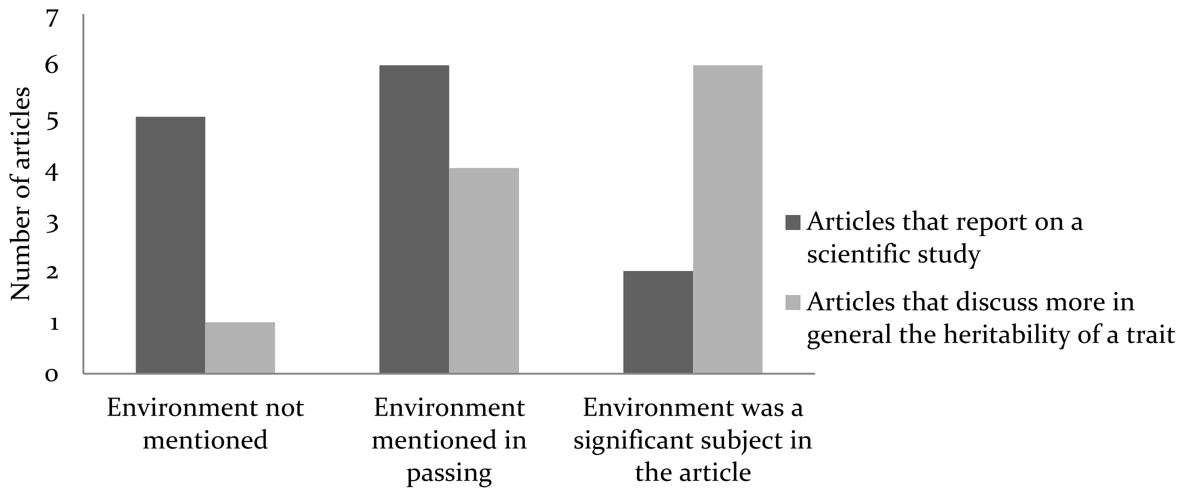

Figure 1. Mentioning of the environment in the news articles.

Expressions that indicate the role of the environment were found in different kinds, like:

> *"Factoren als omgeving en opvoeding zijn waarschijnlijk veel bepalender bij de vraag of iemand gewelddadig gedrag zal vertonen of niet."* (NA29)
> *"Factors like environment and upbringing probably contribute more to whether someone will show violent behavior or not."*

> *"Daarnaast spelen omgevingsfactoren mee. Een partner die je aanspoort bijvoorbeeld."* (NA19)
> *"Environmental factors also play a role. For example a partner who encourages you."*

In the articles that did not mention the environment, the discussed traits were attributed to genes. While in most cases genes were only held partly responsible for the trait, it was not clarified what other factors influenced the trait, for example:

> *"De bevinding suggereert dat een zonverslaving (…) voor een deel genetisch is bepaald."* (NA28)
> *"This finding suggests that sun addiction (…) is partly genetically determined."*

Articles that mentioned the environment in passing did not therefore assert that the role of the environment in the development of the trait was small. In these articles, the environment was often mentioned at the end of the article. All of the articles that treated the role of the environment as a significant subject, did not contain indications for genetic determinism (with the exception of one article (NA2) that had a genetic deterministic title). Most of articles that treated the environment as a significant subject were articles that discussed more in general the heritability of a trait.

Environmental factors that were mentioned were mostly visible environmental factors

If specific environmental factors were mentioned in the articles (most were found in articles in which the environment was a significant part of the article) these were visible environmental factors like smoking, religion and pollution. In three articles, also other environmental factors were found. In one article (NA1) about the heritability of old age, it was explicitly noted that the conditions in the womb are also environmental conditions that can influence the trait and the influence of hormones was discussed. In two other articles (NA4, NA9), early developmental conditions such as complications during pregnancy were mentioned. In both articles, the focus was on environmental influences on autism.

Interaction between genes and environment was mentioned in six articles that did not report on a scientific study

The effect of the environment on the development of the trait was in six articles explained by interaction between environmental and genetic factors. In five articles, the type of interaction was explicated. These were all articles that discussed more in general the heritability of a certain trait and did not in the first place report on a scientific study. In two articles, it was noted that environmental factors may change gene expression (NA1, NA4). In two articles, epigenetic changes were mentioned (NA4, NA24). In two other articles, it was noted that the effect of an environmental factor may differ between people with different genetic make-ups (NA10, NA16). In one article (NA2), the type of interaction was not explicated.

Eight articles mentioned genotypic, environmental and trait variation

In Figure 2 it can be found how many articles mentioned genotypic, environmental and trait variation.

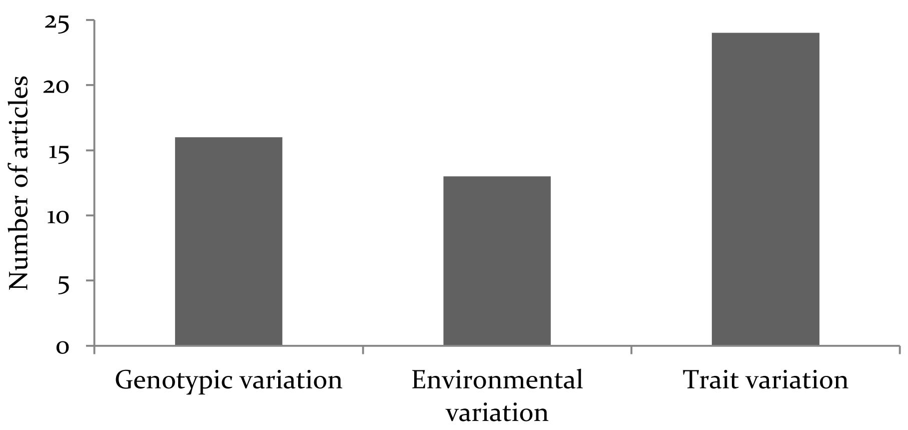

Figure 2. Mentioning of genotypic variation, environmental variation and trait variation in the news articles.

Of the seventeen articles that mentioned genotypic variation, most articles mentioned it explicitly using words like: '*genvarianten*' *('gene variants)* and '*varianten in het genoom*' *('variants in the genome').* Implicit indications for genetic variation were found in two types: first, language that indicates a change or deviation from the 'normal' genes; second, language indicating that genes or genomes can be compared and thus differ.

Of the articles that mentioned the environment, only three did not mention environmental variation. In some cases, it was explicitly mentioned that environmental factors differ between people. Most articles communicated environmental variation implicitly. Found indications were the discussion of environmental factors of which it is generally known that they differ between people or populations, like smoking and socio-economic status, and the choice of words that makes clear that these factors differ, for example:

> *"Volgens Dresch houdt slechts 43 procent van de Nederlandse vrouwen zich aan het advies om tijdens hun zwangerschap dagelijks 400 microgram foliumzuur te slikken."* (NA9)
> *"According to Dresch, only 43% of Dutch women follows the advice to take 400 micrograms of folium acid during their pregnancy."*

Only eight articles mentioned genotypic, trait and environmental variation; three important concepts within the concept of heritability. Six of these were articles that discussed the heritability of a certain trait as the main subject of the article. Mentioned variances (genotypic, trait and environmental) were mainly variances between individuals. A few exceptions were found in which trait differences between countries (NA7), genetic differences between people born in different times (NA1), environmental differences between different times, genotypic differences in time (on individual level) (NA4) and environmental differences between populations (NA16) were mentioned.

Heritability

<u>*Many different words and sentences were found by which articles refer to heritability*</u>

In Table 2, an overview is given of the words and/or sentences that were used to refer to heritability. Words and/or sentences that were similar in nature have been grouped.

Table 2

Grouped words and/or sentences that are being used to refer to (a degree of) heritability and the number of articles in which they were found

Grouped words/sentences and examples	Number of articles
Erfelijk/genetisch (bepaald) (genetically determined/determined by heredity)	14
"Autisme blijkt minder erfelijk bepaald dan gedacht."(NA9)	
("Autism appears to be less heritable than was thought")	
De erfelijkheid van …/de rol/invloed van erfelijkheid (the heredity/heritability of … /the role/influence of heritability/heredity)	9
"Schattingen over de erfelijkheid van (veel) koffiedrinken lopen uiteen van 36 tot 58 procent." (NA5)	
("Estimates about the heritability of drinking (a lot of) coffee range from 36 to 58 percent.")	
(Genetische/erfelijke) aanleg ((genetic/heritable) predisposition)	7
"Toch blijkt erfelijke aanleg voor het ontwikkelen van de ziekte belangrijker." (NA16)	
("Genetic predisposition appears to be more important with developing the disease.")	
Genetische/erfelijke component/factor (genetic/heritable factor)	6
"In families van 110-plussers is de erfelijkheidsfactor waarschijnlijk nog	

hoger.” (NA26) *(“In families of over 110 year olds, the heritable factor is probably higher.”)*	
… zit/ligt in de genen (… lies in the genes)	5
“Verkooptalent zit deels in de genen” (NA6) *(“Commercial talent lies partly in the genes.”)*	
De rol/invloed/effect van genen/DNA (the role/influence/effect of genes/DNA)	4
“…hoe groot de invloed is van het gevonden gen op de ontwikkeling van zonverslaving.” (NA28) *(“…how large the influence of the found gene is on the development of sun addiction.”)*	
…% van de verschillen in … valt toe te schrijven aan/wordt verklaard door genetische verschillen (…% of the differences in … are attributable to genetic differences)	3
“De bijna 700 genvarianten verklaren een vijfde van die erfelijke variatie.” (NA13) *(“The almost 700 gene variants explain one fifth of this heritable variation.”)*	
Bijdrage van de genen/genetische factoren (contribution of genes/genetic factors)	2
“…een veel lagere bijdrage van de genen: slechts 38 procent.” (NA4) *(“… a much smaller contribution of the genes; only 38 percent.”)*	
Genen kunnen voorspellen/verklaren… (genes can predict/explain…)	2
“De resultaten tonen aan dat de genen van de vrouw voor 45% kunnen voorspellen hoe brak ze de volgende dag is. Voor mannen is dit 40%.” (NA27) *(“The results show that the genes of a woman predict for 45% the degree of hangover the next day. For men this percentage is 40.”)*	
… valt te wijten aan de genen (… is attributable to the genes)	1
“Eerdere studies weten tot wel 90 procent van de kans aan genen.” (NA32) *(“Previous studies attributed up to 90% of the chance to genes.”)*	
Erfelijke aanleg is verantwoordelijk voor verschillen in … (genetic predisposition is responsible for differences in …)	1
“Erfelijke aanleg is voor maar liefst 40 procent verantwoordelijk voor verschillen in gevoel van geluk en welbevinden.” (NA24) *(“Genetic predisposition is for 40 percent responsible for differences in feeling happy.”)*	

<u>*Explanations of heritability contained in seven cases its meaning and in fourteen cases the way in which heritability estimates can be determined*</u>

In Figure 3, the number of articles that discuss the meaning of heritability or the way in which heritability can be determined can be found.

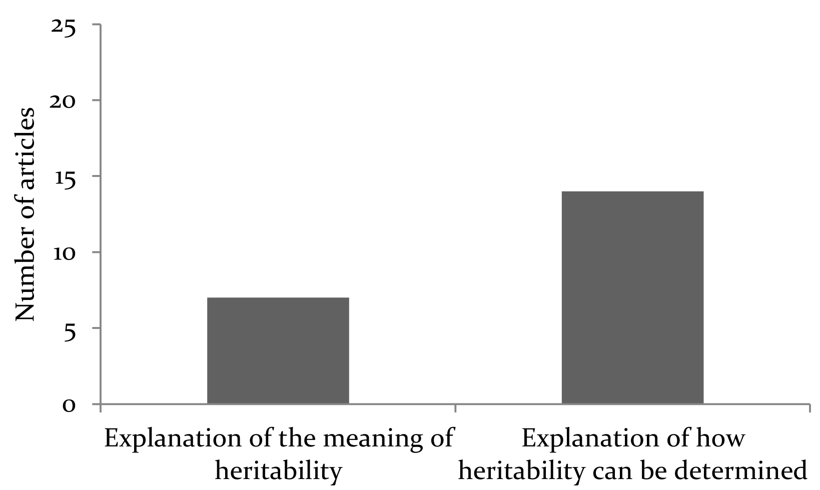

Figure 3. The presence of an explanation of the meaning of heritability and of an explanation of how heritability can be determined in news articles

In all of the cases in which it was made clear how a heritability estimate should be interpreted, at least genotypic and trait variation were mentioned. In four articles (NA2, NA17, NA10, NA24), the meaning of heritability was explicitly given (three of these discussed the same phenotype and were based on an interview with the same scientist), for example:

> *"Dat betekent dat 40 procent van de verschillen in geluk tussen mensen wordt verklaard door genetische verschillen."* (NA2)
> *"That means that 40% of the differences in experiences happiness between people can be explained by genetic differences."*

In the remaining three articles, the meaning of heritability became apparent from the reference to the link between trait variance and gene variance:

> *"Lichaamslengte wordt voor ongeveer 80 procent door erfelijke factoren bepaald. De bijna 700 genvarianten verklaren een vijfde van die erfelijke variatie."* (NA13)
> *"Body length is for almost 80% determined by genetic factors. The almost 700 gene variants explain one fifth of this heritable variation."*

> *"Deze genen zouden kunnen helpen verklaren waarom sommige mensen wel van koffie houden en anderen niet."* (NA36)
> *"These genes may help to explain why some people like coffee and others do not."*

> *"We hebben aangetoond dat de variatie in dit gen samenhangt met de mate waarin jonge mensen symptomen van zonverslaving vertonen."* (NA28)
> *"We showed that the variation of this gene is associated to the degree to which young people show signs of sun addiction."*

A total of fourteen articles explained in some way how heritability can be determined. In most cases the use of twin studies was merely mentioned. In some cases (NA34, NA19, NA7, NA2), it was explained how heritability estimates can be determined with the use of twin studies in more detail, for example:

> *"Bij veel erfelijkheidsonderzoek wordt gebruik gemaakt van tweelingen. Het idee achter tweelingenonderzoek is dat het veel over erfelijkheid zegt als je eeneiige en twee-eiige tweelingen met elkaar vergelijkt. Krijgen eeneiige tweelingen vaker allebei een bepaalde aandoening dan twee-eiigen, dan speelt erfelijkheid een rol."* (NA7)
> *"In most studies concerning heritability, twins are used. The idea behind twin research is that it says a lot about heritability when you compare monozygotic twins with dizygotic twins. If monozygotic twins more often than dizygotic twins develop a certain condition, than heredity is of importance."*

<u>*Only in a few articles a scientific aspect of heritability was mentioned*</u>
For each identified scientific aspect of heritability, it will be described whether it occurred in the articles or not.

Environmental change and time differences can have an effect on heritability estimates.
No indications of this aspect were found in the articles

Phenotypic variation is caused by variation in genotype and environment
This aspect was found in the eight articles that discussed genotypic, environmental and trait variation. In these articles, it was stated that the trait was influenced by genes as well as by environmental factors. In combination with the notions of genotypic and environmental variation, this aspect was thus communicated.

Heritability is the amount of phenotypic variation that is caused by genetic variation
As this aspect contains the meaning of heritability, it was found in the seven articles in which an explanation of heritability was found. In most articles, the meaning of heritability was not explicated. Almost half of the articles contained language that indicated that heritability estimates are applicable on the individual level, denying the fact that it is about phenotypic variation, for example:

> *"In totaal bleek dat de kans om autisme te krijgen voor ongeveer 50 procent in de genen ligt. De rest komt door de omgeving waar iemand in opgroeit."*(NA32)
> *"The chance of getting autism appeared to lie in the genes for about 50%. The rest is caused by the environment in which someone grows up."*

Heritability is a variable estimate/not fixed to a trait
Many articles contained language that implicitly indicates that heritability estimates are fixed, for example by using language such as '*de erfelijkheid van… is…*' *('the heritability of… is….').* In seven articles, it became clear that heritability is variable and not fixed to a trait. In three cases (NA4, NA9, NA32), different heritability estimates from different studies were mentioned, but it remained unclear whether it was meant that different studies (i.e. different populations, environments and time) yield a different heritability, or that the 'true heritability' is not yet known. Four articles (NA26, NA1, NA17, NA27) dealt with population differences with regard to heritability estimates. In NA17, it was made clear that heritability estimates of happiness are different for individuals (50%) and countries (one third). In NA1 and in NA26, it was made clear that heritability estimates for reaching old age are higher for people of old age. In NA27 different heritability estimates are given for men and for women.

Conclusion

In this section, the answer to the research question '*How is the concept of heritability represented in Dutch written news media?*' will be given. In order to answer this question, an analysis tool was developed that concerned the main concepts underlying the heritability definition, the language used to communicate heritability, what heritability means and how it can be determined, and the scientific aspects of heritability.

The analyzed articles were divided into articles that report on a scientific study and articles that discuss more in general the heritability of a trait. Online articles about heritability all belonged to the first type. Differences in the communication of abovementioned categories were observed between the two types of articles. It was found that articles that reported on a scientific study were in general less cautious in the communication of heritability and the concepts underlying its definition. Often the main findings of the scientific heritability study were not correctly communicated. Found differences between the two types of articles will be treated below. No relevant differences were observed between other characteristics of the news articles, like whether the source was a quality newspaper or a popular newspaper.

Many cases of genetic deterministic language were identified. Mostly, language use suggested that genes determine or cause the trait, that genes are responsible for traits, that genes are called after traits or that traits occupy a place in the gene. However, no articles were genetic deterministic in nature; no articles stated that genes determined (the development of) the trait for 100% and genetic determinism was often discouraged, by stating that genes are not the only factors contributing to a trait, or by stating that people can affect a trait by their behavior. A clear difference was seen between titles and main texts, titles often containing genetic deterministic language while language in the articles was more reserved. Only in one title, the role of the environment was mentioned.

In most cases, it was communicated that genes are units of transmission that influence a trait, and not the trait itself or carriers of the trait. Furthermore, mostly in articles that discuss more in general the heritability of a trait, the role of multiple genes in the development of traits was mentioned. Articles that report on a scientific study mostly only mentioned the gene or genes that were important in the study.

The environment was not mentioned in all news articles and was more often lacking in articles that reported on a scientific study. Often, the environment was only mentioned once, often at the end of the article; this however does not mean that the role of the environment is hence communicated to be small. If environmental factors were mentioned, they often comprised visible factors such as diet, activity or socio-economic status. Interaction between genes and environment was mentioned only in articles that discussed more in general the heritability of a trait. Articles belonging to this type often treated the environment, environmental factors and the role of the environment on the development of traits in more detail than articles reporting on a scientific study.

Mentioned genotypic, environmental and trait variation comprised mostly variation between people/individuals, not between populations. All articles mentioned trait variation, however, only a few articles also mentioned both genotypic and environmental variation. These were mostly articles that discussed more in general the heritability of a trait.

Many different kinds of language were used to refer to a heritability estimate in Dutch written news media. Mostly, '*genetisch bepaald*' ('*genetically determined*') or '*erfelijk bepaald*' ('*determined by heredity*') was used. In reports on scientific studies, the word '*erfelijkheid*' was used to communicate the study's findings, indicating that the word '*erfelijkheid*' is in the Netherlands indeed used with the meaning of heredity as well as with the meaning of the heritability.

The meaning of heritability is not often given. At least trait variation and genotypic variation would have to be mentioned and also be related to each other in order to explain the meaning of heritability. Only a few cases were found in which heritability was explicitly explained. In other cases, the meaning of heritability was implicitly given by referring to the link between trait variance and gene variance. More often, ways in which heritability can be determined were mentioned. Only in some cases, it was explained in more detail how heritability estimates can be found with the use of twin studies.

Scientific aspects about heritability were seldom communicated in the news articles. No articles mentioned that environmental change and time differences can have an effect on heritability estimates. A few articles mentioned that heritability estimates are not fixed to a trait, of which in most cases it was made clear that heritability may differ between populations. Only if trait variance, genotypic variance as well as environmental variance are mentioned, it can be communicated that phenotypic variation is caused by variation in genotype and environment. This aspect was thus more often mentioned by articles that discuss more in general the heritability of a trait. It is clear that, while heritability estimates are being mentioned, the concept itself is, in most cases, not treated in more detail.

Discussion

It this study, it was found that media representation of results of heritability studies often misses information or contains language that disturbs a clear message on the meaning of heritability. In this section, limitations of this research are listed. The results of this study will be interpreted in light of results of earlier studies and implications for practice. Also, suggestions are posed for future research.

Limitations

The first limitation of this research is that it is a descriptive study on written text. How the information in the text is interpreted by the readers has not been researched. Based on this study, it cannot be assessed what misconceptions are already present among lay people in the Netherlands, what their previous knowledge is on the topic of heritability and what the effect of news articles is on their knowledge.

Secondly, other sources from which people might get information about heritability have not been analyzed. It might be that citizens also or even mainly find information on the internet, or passively receive information about genetics via TV-programs, affecting their understanding of heritability. Further, it has not been analyzed how the concept of heritability is represented in biology education.

A third limitation is that news articles of only one recent year are analyzed. It cannot be determined whether the media representation of heritability has changed in recent years, for instance due to more research in the field of genetics communication. On the other hand, all published written Dutch news articles that treated the concept of heritability in the year 2014 are analyzed. This provided a complete picture of ways in which the concept of heritability is represented in written news media.

The fourth limitation concerns the generalizability of this study. In this study, recent news articles were used. Whether the results of this study will remain valid in future years depends on many factors. The results of this study cannot fully be extrapolated to other countries, as Dutch language was an important factor in this study. However, the same problems may arise in other languages in which no different words exist for heredity and heritability. An obvious limitation is that a relative small number of articles is used. Proportions are therefore not generalizable, however, the different ways in which heritability and its underlying concepts are represented, are.

Relations to findings of other studies

There are no known studies, in The Netherlands or in other countries, that have studied the representation of heritability in written news media or in other media. The results concerning the concept of heritability that were found in this study are new and cannot directly be compared to other findings. However, there are studies that have focused on the communication of genes and environment in newspapers.

Carver (2013) studied how newspapers frame the gene concept. A striking result of this study was that only 16% of the 600 analyzed articles contained the 'deterministic frame', in which the gene was regarded as a 'definite causal agent' (Carver, 2013). Key words or phrases that indicated this frame were words like 'gene for', 'responsible for' and 'wired in genes'. In this study similar indications were found for genetic determinism, however, the proportion of articles that contained genetic deterministic language was quite large. The low percentage of articles found by Carver can be explained by the distinction that was made in this study between the 'deterministic frame' and the 'symbolic frame', in which genes are regarded as "abstract representations of inheritance" (p. 71), with words and phrases like 'it must be in the genes', 'good genes' or for example: 'I inherited a shopping gene'. In this study, these words and phrases were regarded as indications for genetic determinism. Furthermore, differences between the findings of this study and that of Carver, are caused by differences in material. Whereas in this study only articles that concerned heritability were included, in the study of Carver all types of articles were included.

Many studies have reported that genes are often represented in the media as the causal agents of a trait or disease (Carver, 2013; Condit, 2007; Petersen, 2001; Trumbo,2000). Corresponding to what was found in earlier studies, many cases of genetic deterministic language were identified. However, no articles were genetic deterministic in nature and the view of genetic determinism was often discouraged. These results were not confirmed by earlier studies, however, the focus of this study was on the article as a whole, while earlier studies were mostly quantitative studies. Condit (2007) does describe that while a journalist is not a determinist, over-emphasize of the role of genes and the neglect of the role of the environment might still encourage a deterministic message.

In this study, it was found that the role of environmental factors is often being neglected. Petersen (2001) found that:

> Rarely do news reports mention the influence of non-genetic factors and 'multifactorial' interactions on disorders. (. . . .) In discussions where environmental influences are mentioned, references tend to be made only in passing and, in most cases, well into the article or towards the end of the article. (p. 1262 – 1263).

These findings correspond to what was found in this study concerning articles that report on a scientific study. In some articles, the role of the environment was not mentioned and in other articles, it was mentioned (mostly) in passing and often at the end of the article. However, in articles that did not report on a scientific study but discussed the heritability of a certain trait, many environmental factors were noted and the environment often was a significant part of the article. Still, the environment was mainly characterized through simple environmental factors that people can identify with, which was also found by Horwitz (2005). In some of these articles, the interaction between genes and environment was mentioned, which was not the case for articles that reported on a scientific study. This is also in line with findings of Horwitz (2005), stating that interaction between genes and environment is often left out of news articles. In Horwitz's case study it was also found that genetic influences are overemphasized and environmental effects are underemphasized. The results of this study showed that environment is often addressed in passing, but that articles are not genetic deterministic in nature. Overemphasis of genetic influences is therefore an appropriate term to describe this result.

An important result of this study is that a clear difference in quality of the representation of genes, environment, variation and heritability was seen between the two types of articles. Petersen (2001) describes many aspects of 'stories of discoveries' that were also found in this study, such as bold titles containing genetic deterministic language, the description of the gene as a causative agent and the abovementioned neglect of the role of environmental factors and gene-environment interaction. In the study of Petersen (2001), articles that did not directly report on a scientific study were not used as a distinct category. No other studies were found that were informative on this aspect. The results of our study concerning this aspect can thus not be compared. However, there are multiple reasons to assume that the differences observed between articles reporting on a scientific study and articles discussing the heritability of a certain trait, are plausible. Reasons for framing the gene as *the* cause of a trait found in literature are mainly applicable to news articles that directly report on a scientific study. Interests of the scientist are involved, which may lead to an exaggeration of the implications of their findings (Condit, 2007; Petersen, 2001). It is also plausible that the need to 'hype' the article, which is often done by framing genetics as offering solutions (Carver, 2013), is less prominent with articles that do not report on a scientific study. These articles more often seem to have the goal to discuss the development of a trait, instead of reporting on found genes.

Condit (2007) described that in articles in which a deterministic gene frame is being used, heritability is misrepresented as though it is "a measure of the extent to which genes trump environments, rather than understanding them as a measure of the relative influence of hereditary factors of multiple kinds within a limited range of environments" (p. 817). The results of this study can be interpreted in this fashion, however, further research would be necessary to study whether people indeed interpret the heritability estimate as a measure to which genes trump environment. The articles in which genetic influences are overemphasized, might be at risk to convey this message.

There were no further statements about the representation of heritability in written news media found in scientific literature. What this analysis clarified, is that results concerning the concepts underlying heritability correspond to what was earlier found, however, this mainly applies to articles that report of a scientific study. The difference in quality of the representation of heritability and its underlying concepts between these articles and articles that discuss more in general the heritability of a certain trait, is a new found but plausible difference.

Implications for practice

Implications for biology education

While this research focused on the representation of heritability in written news media, it might have implications for secondary school biology courses. Secondary school biology education is often the only formal learning environment in which students receive information on genetics (Lanie et al., 2004). Science educators worry that biology education does not sufficiently prepare students to cope with modern developments in genetics (Carver, 2013). Trumbo (2000) expressed his concerns about whether biology education would sufficiently prepare students to make sense of reports in the media about genetic determinants of traits. He wonders whether his students are able to understand heritability:

> I am no longer so comfortable with a simplistic presentation of genetics in the general biology curriculum. Will my students who hear about genes for homosexuality, for breast cancer, and for schizophrenia on the nightly news be able to make sense of this information? Are they aware of the limits of the "gene for" language when applied to a diverse population experiencing very different worlds*?* (p.259*).*

The existence of many misconceptions concerning heritability might be due to the lack of information concerning heritability in biology education. It is likely that school textbooks do not cover the topic of heritability, as the Mendelian model is the predominant model in biology education and often a more complex explanation of inheritance is left out (Dougherty, 2009). Biology education could play a part in preventing misconceptions about heritability.

Besides the role of biology education in stimulating better understanding on the concept of heritability, this research also has implications for classroom practices. Teachers should use the results of the study when using news articles in the classroom and be aware of the misconceptions that should be prevented. Nowadays, many teachers make use of external teaching materials such as news articles. Also, in the biology method *Biologie voor Jou,* responsible for 60% of the market share of Dutch biology textbooks (Van Draanen, 2015), in both upper secondary level books students have to use a text shaped like a news article concerning the heritability of exercise behavior and drinking alcohol to answer questions.

If teachers use news articles concerning heritability in their lessons, it is recommendable to critically analyze the article with the students. This way, students are actively involved with the process of finding out what information is in the text and what this information does and does not means. This can be linked to the way in which the heritability estimate was found, in order to guide the students to the awareness that heritability has no meaning for an individual person. Teachers should also discuss that heritability is not a feature of a trait, but a feature of a studied population. It is therefore recommended to use news articles about traits of which students can understand that different environmental situations can lead to different heritability estimates, for example the ability to run fast marathons (differences in training, diet and running shoes nowadays and before) or lung cancer (a population in which everyone smokes and a population in which half of the people smokes). Using news articles concerning heritability and a hypothetical situation in which the heritability is different, may give students further insights in the concept, such as the fact that a high heritability does not have to mean that genes are the most important factors. Furthermore, students are rarely taught about the cooperation of environmental and genetic factors on the development of traits (Dougherty, 2009; Forissier & Clement, 2003; Jiménez-Aleixandre, 2012; Trumbo, 2000). Discussing a news article about heritability may help students to see that the environment and genes both influence traits, hereby avoiding the view of genetic determinism.

Another implication for biology education concerns authors of biology textbooks. They should be aware that the concept of heritability is prone to many misunderstandings. In order to advice authors on the representation of heritability in school textbooks, further research should be done concerning the representation of heritability and its underlying concepts in school textbooks. However, if authors use news articles concerning heritability in textbooks, it is recommended that they think about the purpose with which they do this. If the news article serves to give students insight in heritability, a critical analysis like abovementioned should be stimulated by questions or assignments. Authors should not use news articles about heritability as a means to teach other concepts, hereby risking to convey misconceptions about heritability.

Recommendations for the improvement of the representation of heritability in written news media

Information on the concept of heritability and on the concepts underlying heritability in news articles differs in quality and quantity. Important is that information on heritability and information on its underlying concepts was found to not necessarily be wrong, but mostly lacking. This might indicate that there is low awareness of the concept of heritability among journalists. This conclusion is being supported by Condit (2007), who stated that “Owing to the biases of the journalists and the complexities of the concepts and operationalizations of heritability, it is probably useless to try to use this word with most journalists.” (p. 817). Awareness of the definition of heritability among journalists might improve the representation of heritability in written news articles, as many misconceptions are correlated to a certain part of the definition that is being passed by or misinterpreted. A more careful consideration of the representation of the concepts underlying heritability and the concept of heritability itself might improve the communication of heritability. An explanation of what a heritability estimate implies could possibly prevent the communication of misconceptions concerning heritability.

Nine misconceptions concerning heritability were identified in the theoretical background. Below, for each misconception, it will be described what indications in the analyzed texts may stimulate the misconception and recommendations are given how to avoid this.

1) Heritability estimates indicate what proportion of a trait is passed on to the next generation

In this misconception ‘proportion of a trait’ is used instead of the part of the definition ‘proportion of phenotypic variance’. Underlying this misconception is the notion that traits are passed on instead of genes. In some cases, it was found that genes were seen as the actual traits or as carriers of traits. Unawareness of gene function might enhance deterministic thinking (Gericke, 2009), and thus stimulate this misconception. The stimulation of this misconception can be prevented by not naming a gene after a trait, not using 'gene for…' language and not stating that a trait is 'in the genes'. In most news articles, the concept of gene was described as a unit of transmission, influencing a trait. This notion was stimulated by describing or explaining the way in which genes affect a trait. By explaining the function of the gene, it is clarified that the way from genes toward the trait contains multiple steps. Also, words like '*samenhangt met' ('associated with')*, '*beïnvloedt*' *('influences')* and '*een rol spelen bij' ('play a role in')*, deny that genes 'contain' traits or are the actual traits in miniature and are thus recommended to use.

2) Heritability estimates indicate causal roles of genes and environment on the trait on the individual level

In this misconception, heritability estimates are applied to the individual level instead of to the population level. It is expected that without an explanation of heritability, lay people may connect a given heritability to individual cases. Heritability was only explained in a few cases. Furthermore, heritability estimates were often related directly to individual cases. This might influence people's health behavior, especially in combination with the third misconception. It is therefore recommendable to explain heritability by means of exemplifying what a given heritability estimate means (explicitly stating that the found heritability estimate cannot be used to explain how a trait is caused in individual cases). Furthermore, the notion that traits can be predicted on the individual level, should be avoided.

3) High heritability indicates genetic determination

Genetic determination implies a sole role for genetic factors in the development of the trait. This is not the case for high heritability, because changes in the environment can alter the phenotype. This aspect was never mentioned in news articles. Genetic deterministic language and the lack of mentioning of the role of the environment might stimulate this misconception. Most articles contained genetic deterministic language and are thus at risk to communicate genetic deterministic messages. Genetic deterministic language should be avoided and the role of the environment should be explicated.

4) *Heritability is a fixed property of a trait.*

In many articles, language use such as '*de erfelijkheid van … is…*' *('the heritability of… is…')* points to a fixed estimate belonging to a trait. As was described in the theoretical background, heritability is a feature of the studied population and not of a trait. This aspect of heritability was nevertheless not mentioned by most articles. In none of the articles it was mentioned that environmental change and time differences can have an effect on heritability estimates. A few articles mentioned that heritability estimates may differ between populations. In order to discourage this misconception, it could be helpful to mention different studies leading to different estimates, however, it should be clarified that this may be due to for instance different environments or gene pools. Furthermore, it is important to note that found heritability estimates are restricted to the population, environment and time in which it was studied, so it is clear that the heritability estimate does not have to be valid for the reader.

5) Heritability estimates explain the proportion of disease cases that are attributable to genetic or environmental factors.

No indications were found in the news articles that point to this misconception.

6) Low heritability indicates that genes play little part in the development of a trait.

There were no indications that this misconception is likely to be conveyed by written news media found in literature. As this misconception might stimulate the reversed misconception that high heritability means genetic determination, this misconception would also be important to prevent. In order to prevent this misconception it would be important to note that genes might still be of importance, even though heritability is low.

7) Low heritability indicates no genetic variation

It is not be expected that this misconception would arise, as it requires understanding of the definition of heritability. Furthermore, this misconception is not likely to influence health-related behavior or family planning. No indications were found in this study that point to this misconception.

8) Heritability is informative about the nature of between-group differences or shifts in phenotypes over time.

This misconception also requires understanding of heritability and is thus not likely to arise among lay people and to influence their behavior. Indications for this misconception were also not found in this study.

9) Large heritability implies genes of large effect.

It was communicated by some articles that many genes of small effect influence traits. Articles that reported on a scientific study, are at risk of communicating this misconception, as most of these articles only mention the genes that were found in the study. While the notion that one or few genes affects a trait is not likely to affect people's health-related behavior or family planning, it does hinder basic understanding of genetic concepts.

Further research

In further research, it should be tested what the effects of texts in news articles and school textbooks are on people's knowledge of heritability and on misconceptions about heritability. People's responses to news reports about genetics are not directly linked to what is reported in the media. The impact of information in the media depends for example on prior knowledge and experience. This should thus be tested in further studies. The effects on people's understanding of heritability of current ways in which heritability is communicated in which information is lacking, should be compared to the effects of texts in which heritability is explained and in which the communication of misconceptions is avoided.

Literature

Boerwinkel, D. J., & Waarlo, A. J. (2010). Genomics education for decision-making: research on socioscientific learning and teaching. *Genomics Education for Decision-making*, *2*, 15. Retrieved from http://www.society-genomics.nl/uploads/media/Genomics_Education_for_Decision_Making.pdf#page=15

Boujemaa, A., Pierre, C., Sabah, S., Salaheddine, K., Jamal, C., & Abdellatif, C. (2010). University students' conceptions about the concept of gene: Interest of historical approach. *US-China Education Review*, *7*(2), 9-15. Retrieved from https://halshs.archives-ouvertes.fr/hal-01024976/document

Carver, R. B. (2013). *Framing the gene. A science communication study of how newspapers frame different meanings of the gene concept, with applications for science education* (Doctoral dissertation, Universitetet i Oslo, Norway). Retrieved from http://urn.nb.no/URN:NBN:no-37053

Condit, C. M. (2007). How geneticists can help reporters to get their story right. *Nature Reviews Genetics, 8*, 815-820. doi:10.1080/00219266.2003.9655857

Crawley, C. E. (2007). Localized debates of agricultural biotechnology in community newspapers: A quantitative content analysis of media frames and sources. *Science Communication, 28,* 314-346. doi:10.1177/1075547006298253

Dougherty, M. J. (2009). Closing the gap: Inverting the genetics curriculum to ensure an informed public. *The American Journal of Human Genetics, 85,* 6-12. doi:10.1016/j.ajhg.2009.05.010

Emery, J., Kumar, S., & Smith, H. (1998). Patient understanding of genetic principles and their expectations of genetic services within the NHS: A qualitative study. *Community Genetics, 1*, 78-83. doi:10.1159/000016141

English Oxford Dictionary online (2014). Retrieved from http://www.oxforddictionaries.com/

Evans, W. A., Krippendorf, M., Yoon, J. H., Posluszny, P., & Thomas, S. (1990). Science in the prestige and national tabloid presses. *Social Science Quarterly, 71,* 105-117. Retrieved from http://connection.ebscohost.com.proxy.library.uu.nl/c/articles/64138418/science-prestige-national-tabloid-presses

Feil, R., & Fraga, M. F. (2012). Epigenetics and the environment: emerging patterns and implications. *Nature Reviews Genetics, 13,* 97-109. doi:10.1038/nrg3142

Feresin, E. (2009). Lighter sentence for murderer with 'bad genes'. *Nature, 10*, p. 1038. doi:10.1038/news.2009.1050

Forissier, T. & Clement, P. (2003). Teaching 'biological identity' as genome/environment interactions. *Journal of Biological Education*, *37,* 85-90. doi:10.1080/00219266.2003.9655857

Frazer, K. A., Murray, S. S., Schork, N. J., & Topol, E. J. (2009). Human genetic variation and its contribution to complex traits. *Genetics, 10,* 241 – 251. doi:10.1038/nrg2554

Geller, G., Bernhardt, B. A., & Holtzman, N. A. (2002). The media and public reaction to genetic research. *JAMA, 287*(6), p.773. doi:10.1001/jama.287.6.773-JMS0213-3-1

Gericke, N. (2009). *Science versus School-science: Multiple models in genetics-The depiction of gene function in upper secondary textbooks and its influence on students' understanding* (doctoral thesis, Karlstads Universitet). Retrieved from http://www.diva-portal.org/smash/get/diva2:128104/FULLTEXT02.pdf

Gericke, N. M., & Hagberg, M. (2007). Definition of historical models of gene function and their relation to students' misunderstanding of genetics. *Science & Education, 16,* 849-881. doi: 10.1007/s11191-006-9064-4

Hertog, J. K. & McLeod, D. M. (2003). A multiperspectival approach to framing analysis: A field guide. In S. D. Reese, O. H. Gandy, & A. E. Grant (Eds.), *Framing public life: Perspectives on media and our understanding of the social world* (pp. 139-161). Mahwah, NJ: Lawrence Erlbaum Associates.

Holzman, N. A., Bernhardt, B. A. Mountcastle- Shah, E., Rodgers, J. E., Tambor, E., & Geller, G. (2005). The quality of media reports on discoveries related to human genetic diseases. *Community Genetics, 8*, 133-144. doi:10.1159/000086756

Horwitz, A. V. (2005). Media portrayals and health inequalities: A case study of characterizations of gene x environment interactions. *Journals of Gerontology Series B*, *60*(2), 48. Retrieved from http://www.spusa.org/pubs/health_med/mental_health/JGerontologyMediaandGenes.pdf

Hunter, D. J. (2005). Gene-environment interactions in human diseases. *Nature Reviews Genetics, 6*, 287–298. doi:10.1038/nrg1578

Jablonka, E., & Raz, G. (2009). Transgenerational epigenetic inheritance: prevalence, mechanisms, and implications for the study of heredity and evolution. *The Quarterly review of biology*, *84*(2), 131-176. doi:10.1086/598822

Jennings, B. (2004). Genetic literacy and citizenship: possibilities for deliberative democratic policymaking in science and medicine. *The Good Society, 13*(1), 38-44. doi:10.1353/gso.2004.0028

Jiménez-Aleixandre, M. P. (2012). Determinism and Underdetermination in Genetics: Implications for Students' Engagement in Argumentation and Epistemic Practices. *Science & Education*, *23*(2), 465-484. doi:10.1007/s11191-012-9561-6

Kaphingst, K. H., Lachance, C. R., & Condit, C. M. (2009). Beliefs about heritability of cancer and health information seeking and preventive behaviors. *Journal of Cancer Education*, *24*, 351–356. doi:10.1080/08858190902876304

Lafayette, D. D., Abuelo, D., Passero, M. A., & Tantravahi, U. (1999). Attitudes toward cystic fibrosis carrier and prenatal testing and utilization of carrier testing among relatives of individuals with cystic fibrosis. Journal of Genetic Testing, 8,17–36. Retrieved from http://link.springer.com/article/10.1023/A:1022830519602

Lanie, A. D., Jayaratne, T. E., Sheldon, J. P., Kardia, S. L., Anderson, E. S., Feldbaum, M., & Petty, E. M. (2004). Exploring the public understanding of basic genetic concepts. *Journal of genetic counseling*, *13*(4), 305-320. doi:1059-7700/04/0800-0305/1

Laugksch, R. C. (2000). Scientific literacy: a conceptual overview. *Science Education, 84*(1), 71-94. doi:10.1002/(SICI)1098-237X(200001)84:1<71::AID-SCE6>3.0.CO;2-C

Lush, J. L. (1940). Intra-sire correlations or regressions of offspring on dam as a method of estimating heritability of characteristics. *American Society of Animal Production, 33*, 293–301. doi:10.2134/jas1940.19401293x

Macnamara. J. (2003). Media content analysis: Its uses, benefits and best practice methodology. *Asia Pacific Public Relations Journal, 6*(1), 1–34. Retrieved from http://amecorg.com/wp-content/uploads/2011/10/Media-Content-Analysis-Paper.pdf

Marteau, T. M., & Lerman, C. (2001). Genetic risk and behavioural change. *Britisch Medical Journal*, *322*(7293), 1056-1059. Retrieved from http://www.ncbi.nlm.nih.gov/pmc/

articles/PMC1120191/

Marteau, T., Senior, V., Humphries, S. E., Bobrow, M., Cranston, T., Crook, M. A., ...Wray, R. (2004). Psychological impact of genetic testing for familial hypercholesterolemia within a previously aware population: A randomized controlled trial. *American journal of medical genetics, 128A,* 285-293. doi:10.1002/ajmg.a.30102

Matthes, J. & Kohring, M. (2008). The Content Analysis of Media Frames: Toward Improving Reliability and Validity. *Journal of Communication, 58,* 258-279. doi:10.1111/j.14602466.2008.00384.x

Mays, N., & Pope, C. (1995). Qualitative Research: Rigour and qualitative research. BMJ, 311, 109-112. doi:http://dx.doi.org/10.1136/bmj.311.6997.109

Monaghan, P. (2008). Early growth conditions, phenotypic development and environmental change. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *363*(1497), 1635-1645. doi:10.1098/rstb.2007.0011

Mountifield, R., Bampton, P., Prosser, R., Muller, K., & Andrews, J. M. (2009). Fear and fertility in inflammatory bowel disease: A mismatch of perception and reality affects familiy planning decisions. *Inflammatory Bowel Disease, 15*(5), 720-725. doi:10.1002/ibd.20839

Nationaal Onderzoek Multimedia (2013). *NOM Print Monitor 2013-I/2013-II.* Retrieved from http://www.nommedia.nl/upload/documenten/gemiddeld-bereik-website-nom-npm-2013-i-2013-ii.pdf

Nehm, R. H. & Reilly, L. (2007). Biology majors' knowledge and misconceptions of natural selection. *BioScience*, *57*(3), 263-272. doi:http://dx.doi.org/10.1641/B570311

NPD Nieuwsmedia (2013). *Jaarverslag 2013*. Retrieved from http://ndpnieuwsmediajaarver slag.nl/jaarverslag2013/

Owen, M. J. & McGuffin, P. (1997). Genetics and psychiatry. *The British Journal of Psychiatry, 17*(1), 201-202. doi:10.1038/news.2009.1050

Parrott, R. L., Silk, K., Weiner, J., Condit, CM., Harris, T., & Bernhardt, J. (2004). Deriving lay models of uncertainty about genes' role in illness causation to guide communication about human genetics. *Journal of Communication, 54*(1), 105-122. doi:10.1111/j.1460-2466.2004.tb02616.x

Parrott, R. L., Silk, K. J., & Condit, C. (2003). Diversity in lay perceptions of the sources of human traits: genes, environments, and personal behaviors. *Social Science & Medicine, 56,* 1099-1109. doi:10.1016/S0277-9536(02)00106-5

Petersen, A. (2001). Biofantasies: genetics and medicine in the print news media. *Social Science & Medicine, 52,* 1255–1268. doi:10.1016/S0277-9536(00)00229-X

Pope, C., & Mays, N. (2000). Analysing qualitative data. *BMJ*, *320*, 114-116. doi:http://dx.doi.org/10.1136/bmj.320.7227.114

Rice, T. K. (2008). Familial resemblance and heritability. *Advances in genetics,60*, 35-49. doi:10.1016/S0065-2660(07)00402-6

Richards, M., & Ponder, M. (1996). Lay understanding of genetics: a test of a hypothesis. *Journal of Medical Genetics, 33,* 1032-1036. doi:10.1136/jmg.33.12.1032

Sadler, T. D. (2004). Moral and Ethical Dimensions of Socioscientific Decision-Making as Integral Components of Scientific Literacy. *Science Educator, 13*(1), 39-48. Retrieved from http://files.eric.ed.gov/fulltext/ED481210.pdf

Senior, V., Marteau, T. M., & Peters, T. J. (1999). Will genetic testing for predisposition for disease result in fatalism? A qualitative study of parents responses to neonatal screening for familial hypercholesterolaemia. *Social Science & Medicine, 48,* 1857-1860. doi:10.1016/S0277-9536(99)00099-4

Stoltenberg, S. F. (1997). Coming to terms with heritability. *Genetica, 9*, 89-96. doi:10.1007/BF02259512

Thomas, J. (2000). Learning about genes and evolution through formal and informal education. *Studies in Science Education*, *35*(1), 59 – 92. doi:10.1080/03057260008560155

Tremblay, T. & Gagné, F. (2001). Beliefs of students talented in academics, music, and dance concerning the heritability of human abilities in these fields. *Roeper Review*, *23*(3), 173-177. doi:10.1080/02783190109554091

Trumbo, S. (2000). Introducing students to the genetic information age. *The American Biology Teacher, 62*(4), 259-261. Retrieved from http://www.jstor.org/stable/4450892?origin= JSTOR-pdf&seq=1#page_scan_ tab_contents

Van Dale online (2011). Retrieved from http://www.vandale.nl/zoeken/zoeken.do?crowd. token_key=cSnMCoOSuHjDuWOofb2csAoo

Van Draanen, D. (2015). *The status of the concepts 'hereditary trait' and 'phenotype' in secondary school textbooks* (master's thesis). Utrecht University, Utrecht.

Verenigde Internet Exploitanten, Platform media-adviesbureaus & GfK (2014). *Dutch Digital Media Measurement oktober 2014*. Retrieved from http://www.vinex.nl/resultaten/ archief/

Vineis, P., & Pearce, N. E. (2011). Genome-wide association studies may be misinterpreted: genes versus heritability. *Carcinogenesis*, *32*(9), 1295-1298. doi:10.1093/carcin/bgr087

Visscher, P. M., Hill, W. G., & Wray, N.R. (2008). Heritability in the genomics era – concepts and misconceptions. *Genetics, 9*, 255-266. doi:10.1038/nrg2322

Williams, M., Montgomery, B. L., & Manokore, V. (2012). From phenotype to genotype: Exploring middle school students' understanding of genetic inheritance in a web-based environment. *The American Biology teacher, 74*(1), 35-40. doi:10.1525/abt.2012.74.1.8

Appendices

Appendix A: Technical information on the calculation of heritability

As heritability measures the proportion of phenotypic variance between individuals that can be explained by their genetic variances, the parameter of heritability is a ratio with a numerator and a denominator.

$$h^2 = var\ (A)\ /\ var\ (P)$$

Heritability is the variation that is due to genetic differences divided by the total observed phenotypic variance in the trait (var (P)). The phenotypic variance is the sum of genetic variance and environmental variance. Genetic differences are used differently according to the two existing types of heritability, namely narrow-sense heritability (h^2) and broad-sense heritability (H^2). Broad-sense heritability takes into account all differences in genotypes, which include genetic effects that are based on sharing two copies (alleles) of a gene. However, parents only transmit each one allele to each offspring. Therefore, most relatives share only single or no alleles. As families are often being used to find heritability estimates, it is therefore important to take into account the genetic factors that cause resemblance between family members. These are called the additive genetic values (var (A)). Therefore, the narrow-sense heritability is the usual parameter used by geneticists and this is the type of heritability that is central in this paper (e.g. Stoltenberg, 1997; Visscher et al., 2008).

There are different study designs with which heritability estimates can be calculated. The most commonly approaches to estimate heritability are family studies and animal model studies (Rice, 2008; Visscher et al., 2008). All ways of estimating heritability rely on the question whether family members who have similar genotypes resemble each other more than less related family members do (Lush, 1940). A common approach to determining heritability is using studies of monozygotic (MZ) and dizygotic (DZ) twins (Rice, 2008; Visscher et al., 2008). MZ twins share 100% of their genes in common. Therefore, any phenotypic variance will be due to environmental differences. DZ twins share averagely 50% of their genome. Their phenotypic variance is therefore due to differences in genetic factors and also to differences in environmental factors. For both types of twins the common environment is assumed to be the same (the choice of DZ twins instead of normal siblings is better because DZ twins, like MZ twins, share the environment in de womb). If MZ twins resemble each other more than DZ twins do, this indicates that the trait is influenced by genes. The genetic variance is the difference of phenotypic variance between MZ and DZ twins. The same principles can be applied to nuclear family studies, adoption studies (in which twins are separated at birth) and animal studies (Rice, 2008).

There are also different formulas that can be used to calculate heritability. An example is Falconer's formula, which is often used in twin studies (Rice, 2008). Falconer's formula calculates heritability by multiplying the difference between trait concordance of MZ twins and that of DZ twins by two. For example, the concordance of IQ of MZ twins is .86 and the concordance of IQ of DZ twins is .60. MZ twins, who share 100% of their genome, are thus more similar than DZ twins, who share 50% of their genome. As the common environment is assumed to be the same, this difference is due to their difference in genetic make-up. If sharing an extra half of the genome means .86 - .06 = .26 extra concordance, sharing a full genome explains 52% of the trait.

Appendix B: Tool for analysis of media articles

Rater:	Enter the name of the coder.	**Code:**	NA
Newspaper:	Enter the name of the newspaper.	**Date of article:**	Click here to enter a date.
Title of article:	Enter the title of the article.	**Length:**	Enter the number of words
The article…:	☐Reports about a scientific study, or: ☐Discusses the heritability of a certain trait as the main subject		

1. Message

1.1 Main message

Message of title:	Enter the message that is communicated in the title (might be the title itself).	
Main message of article:	Enter the main message of the article (in one sentence)	
Do the main message and the title message correspond?	☐Yes ☐No ☐Not applicable	If not, what is the main difference? If not applicable, why not?

1.2 Scientific study (if applicable)

Scientific study:	Enter the title of the paper and the authors or the topic of the research and the scientists.	
Main findings:	Enter the main findings (connected to heritability) of the research (in one sentence).	
Does the main message correspond with the main findings of the scientific study?	☐Yes ☐No	If not, what is the main difference?
What implications of the study's findings does the article communicate?	Enter the implications that are given in the text. These may be quotations.	
Are the communicated implications in line with the study results? Why not?	☐Yes ☐No	If the communicated implications are not in line with the study results, fill in in what way they differ.

2. Concepts underlying heritability

2.1 Genes

Is the development of the trait attributed to one or to more than one gene?	☐One gene is responsible ☐More than one gene is responsible	Click here to enter explanatory quotations and/or text.
Are possible links (proteins, molecules, processes, mechanisms etc.) between the gene and the phenotype mentioned?	☐Yes ☐No	Click here to enter explanatory quotations and/or text.
How is the concept of gene described?	☐As a carrier of the phenotype (or as the miniature phenotype). ☐As the unit of transmission (separate from the trait) ☐Not applicable	Click here to enter explanatory quotations and/or text.
Indications of genetic determinism:	☐Yes ☐No ☐The article discourages genetic determinism	Click here to enter text. Quote all of the indications for genetic determinism or indications that the article avoids genetic determinism.

2.2 Environment

Is the environment mentioned? Is it a significant subject in the article or is it mentioned in passing?	☐Yes, environment is a significant subject in the article ☐Yes, in passing ☐No
Where in the article is the environment mentioned?	☐Title ☐In the first ¼ of the article ☐In the second ¼ of the article ☐In the third ¼ of the article ☐In the fourth ¼ of the article
What environmental factors are mentioned / with what words is the environment addressed?	Click here to enter the environmental factors that are mentioned and/or quote the words with whom the environment is addressed.

2.3 The roles of genetic and environmental factors in the development of traits		
Does the article assign influences in the development in the trait to genes and/or environmental factors?	☐Only to genes. ☐Only to environmental factors. ☐Mostly to genes. ☐Mostly to environmental factors. ☐Both to genes and environmental factors equally. ☐Both to genes and environmental factors (no relative contribution mentioned). ☐To interaction between genes and environmental factors. ☐To personal choices ☐To chance	Click here to enter explanatory quotations and/or text.
If interaction was mentioned, what type(s) of interaction is this?	☐Environmental factors influences gene expression. ☐Environmental influences on gene expression being transmitted from earlier generations (via epigenetic changes) ☐The effect of an environmental factor may differ between people with different genetic make-ups. ☐The environment affects the outcome of a genotype. ☐Type of interaction was not explicated.	Click here to enter explanatory quotations and/or text.

2.4 Variation		
Does the article mention genotypic variation? With what words?	☐Yes, implicitly ☐Yes, explicitly ☐No	Click here to enter explanatory quotations and/or text.

Does the article mention environmental variation? With what words?	☐Yes, implicitly ☐Yes, explicitly ☐No	Click here to enter explanatory quotations and/or text.
Does the article mention trait variation? With what words?	☐Yes, implicitly ☐Yes, explicitly ☐No	Click here to enter explanatory quotations and/or text.

3. Heritability

3.1 Heritability language

What words are being used when the article refers to heritability?	Click here to enter the words that are being used when the article refers to heritability. The aricle refers to heritability when it discusses a degree to which something can be inherited or to which genes and/or environmental factors influence traits.

3.2 Meaning of heritability

Is the concept of heritability explained? In what words?	☐Yes ☐No	Click here to enter the quotations from the text that express the meaning of heritability (implicitly or explicitly).
Is the way in which heritability can be determined explained?	☐Yes ☐No	Click here to enter the quotations from the text that express the way in which heritability can be determined.
What (scientific) aspects of heritability are mentioned? (multiple options possible)	☐Phenotypic variation is caused by variation in genotype and environment. ☐Heritability is the amount of variation in phenotype that is being caused by genetic variation. ☐Heritability is a variable estimate / not fixed to a trait. ☐Environmental change and time differences can have an effect on heritability estimates.	Click here to enter explanatory quotations and/or text.

4. Other distinctive features of the text

Click here to enter text.

5. Misconceptions

Which misconceptions are likely to be reinforced or weakened?

Heritability estimates indicate what proportion of *a trait* is passed on to the next generation	☐ Indications present ☐ Indications for the discouragement of this misconception ☐ Indications absent	Click here to enter explanatory text (these might be quotations and/or findings from previous category analyses).
Heritability estimates indicate causal roles of genes and environment on the trait on the individual level	☐ Indications present ☐ Indications for the discouragement of this misconception ☐ Indications absent	Click here to enter explanatory text (these might be quotations and/or findings from previous category analyses).
Heritability estimates explain the proportion of trait/disease cases that are attributable to genetic or environmental factors	☐ Indications present ☐ Indications for the discouragement of this misconception ☐ Indications absent	Click here to enter explanatory text (these might be quotations and/or findings from previous category analyses).
Heritability is a fixed property of a trait	☐ Indications present ☐ Indications for the discouragement of this misconception	Click here to enter explanatory text (these might be quotations and/or findings from previous category analyses).

	☐ Indications absent	
(High) heritability indicates genetic determination	☐ Indications present ☐ Indications for the discouragement of this misconception ☐ Indications absent	Click here to enter explanatory text (these might be quotations and/or findings from previous category analyses).
Low heritability indicates that genes play little part in the development of a trait	☐ Indications present ☐ Indications for the discouragement of this misconception ☐ Indications absent	Click here to enter explanatory text (these might be quotations and/or findings from previous category analyses).
Low heritability indicates no genetic variation	☐ Indications present ☐ Indications for the discouragement of this misconception ☐ Indications absent	Click here to enter explanatory text (these might be quotations and/or findings from previous category analyses).
Heritability is informative about the nature of between-group differences or shifts in phenotypes over time	☐ Indications present ☐ Indications for the discouragement of this misconception ☐ Indications absent	Click here to enter explanatory text (these might be quotations and/or findings from previous category analyses).
Large heritability implies genes of large effect	☐ Indications present ☐ Indications for the discouragement of this misconception ☐ Indications absent	Click here to enter explanatory text (these might be quotations and/or findings from previous category analyses).

Appendix C: Sources

Code	Title	Newspaper	Published on:
NA1	Ook u kunt 120 worden. In principe	De Volkskrant	20-12-2014
NA2	Op zoek naar genen die ons geluksgevoel bepalen	De Volkskrant	22-05-2014
NA4	Duizend wegen naar autisme	NRC Handelsblad	07-06-2014
NA5	Koffieleut? Komt door je genen; cultureel bepaald	NRC Next	17-10-2014
NA6	Goede genen maken iemand tot een goede verkoper	Trouw	31-05-2014
NA7	Vertrouwen zit niet in onze genen	Volkskrant	08-04-2014
NA8	Autismegenen zijn bij veel mensen te vinden	NRC Next	21-07-2014
NA9	Autisme blijkt minder erfelijk dan gedacht	AD	21-10-2014
NA10	Geluk ten dele erfelijk, maar hoe?	Het Parool	28-06-2014
NA12	Niet alleen het gehoor vormt de liefde voor muziek	Trouw	12-03-2014
NA13	Nu al 700 genen voor lengte – straks duizenden	NRC Handelsblad	06-10-2014
NA16	Veranderd gen nekt astmapatiënt	Reformatorisch Dagblad	29-03-2014
NA17	Met een korrel zout	De Volkskrant	22-11-2014
NA19	Is bankhangen een kwestie van erfelijke aanleg?	De Telegraaf	02-06-2014
NA24	Met een beetje geluk	De Telegraaf	18-01-2014
NA25	'Succes zit in de genen'	AD	15-08-2014
NA26	Gen voor lang leven is onvindbaar	NRC Handelsblad	13-11-2014
NA27	Brak? Niet jouw schuld	NOS.nl	25-08-2014
NA28	Mogelijk gen voor zonverslaving geïdentificeerd	NU.nl	02-12-2014
NA29	Twee genen gelinkt aan gewelddadig gedrag	NU.nl	28-10-2014
NA32	Genen en omgeving net zo belangrijk bij ontstaan autisme	NU.nl	04-05-2014
NA33	Aanleg voor wiskunde en lezen beïnvloed door dezelfde genen	NU.nl	09-07-2014
NA34	Overgewicht erfelijk bepaald door darmflora	NU.nl	08-11-2014
NA36	Liefde voor koffie is genetisch bepaald	NU.nl	08-10-2014