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ORIGINAL RESEARCH

Public Understanding of Behavioral Genetics: Integrating Heuristic Thinking, Motivated Reasoning and Planned Social Change Theories for Better Communication Strategies

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Abstract
The field of behavioral genetics is experiencing a revolution following the development of genome-wide association studies and the availability of large datasets from international consortia. This rapid change could increase the existing gaps between basic research, translation, and public understanding of science. In the present work, we aim to synthesize key explanations of how public understanding of socio-scientific issues develop. We propose that integrating dual-process, motivated reasoning, and change management theories will increase the extent to which we understand, and can change, how people respond to findings from behavior genetics.

Keywords Genetic essentialism · Deficit model · Heuristics · Information processing · Motivated reasoning · Planned change

Introduction

Scientific research findings can have marked social ramifications, dividing public opinion. Examples of such *socio-scientific issues* (Sadler 2004) are climate change, genetically modified organisms, stem cells, and alternative energy sources. The field of behavioral genetics in particular often gives rise to socio-scientific dilemmas, such as the debate about the contribution of genetic variants to educational attainment. Some major communication challenges that we face in behavioral genetics are: (i) how to communicate findings of genetic influence on behavior to the general public, and (ii) how to convey information regarding a polygenic risk profile to patients and their families. Unfortunately, misconceptions about socio-scientific issues are frequent, and people often misunderstand or respond negatively to findings from these areas (Bubela et al. 2009; Kahan 2015; Sinatra et al. 2014). While science communication research in other socio-scientific areas, such as climate change, has incorporated complex psychological theories to understand and enhance public understanding, behavioral genetic science communication often operates under the assumption that people are rational thinkers, and that misunderstanding of results stems from a lack of knowledge.

In this paper, we review previous work on how people respond to scientific information, and then apply social psychological insights to explain why the public might have difficulties engaging with findings from behavioral genetics. More specifically, we address the importance of systematic and heuristic information processing in understanding of scientific information, its connection with genetic essentialism, and the role of attitudes and values when evaluating scientific information. We conclude by proposing the use of persuasion and planned change theories for communication and educational campaigns to improve public understanding of contemporary behavioral genetic research.

Genetic essentialism, attitudes towards genetics, and the problem of literacy

One of the main concerns among scientists about disseminating genetic explanations of complex behavior is that people will interpret any genetic contribution as inferring

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determinism. When a behavior is viewed as being influenced by genetic factors, people tend to (i) view such behavior as less malleable, (ii) disregard other causal explanations, (iii) perceive exaggerated genetic differences between groups, and (iv) perceive partially genetically determined behaviors as natural, and therefore acceptable (Dar-Nimrod and Heine 2011; Heine et al. 2017). The phenomenon of perceiving genes as the underlying *essences* that make people and groups categorically different from one another has been termed *genetic essentialism*, and is considered a specific case of psychological essentialism (Lynch et al. 2018). The psychological essentialism hypothesis states that people are likely to see different people, creatures, objects, and groups as having underlying essences, and that such essences are the fundamental nature of something or someone, what makes it what or who it is (Gelman 2003; Medin and Ortony 1989).

Negative social outcomes can result from exaggerated or faulty essentialist beliefs. For example, the more that people endorse genetic essentialist beliefs, the more likely they are to report racism and sexism, pessimistic thoughts about expected recovery from a disease, and sympathy for eugenic practices (for a review of examples and consequences of genetic essentialism, see Heine et al. 2017). Such interpretations of genetic explanations of behavior are typically viewed as unwarranted and reflecting a lack of information or understanding. In view of this, the scientific community has considered increasing genetic literacy levels in society a priority. This, it is believed, will prevent misunderstandings and promote realistic interpretations of complex trait genetics (Chapman et al. 2018; Heine et al. 2017).

In support of the need for more genetic literacy, surveys suggest that, while the public has some familiarity with terms used in genetics, there are substantial gaps in their understanding of the underlying concepts (Condit 2010b; Erby et al. 2008; Morris et al. 2003). Studies also show that misconceptions about the meaning of increased genetic risk, carrier risk, and probability of passing on genetic susceptibility to their offspring are common (Lea et al. 2011). There may be also specific difficulties associated with understanding the polygenic nature of behavioral traits, such as psychological disorders (Chapman et al. 2018; Crosswaite and Asbury 2018), and confusion about behavioral genetics is widespread even among well-educated individuals (Chapman et al. 2018) and health professionals (Dougherty et al. 2014).

The general public also is prey to confusion about genetic technologies; public attitudes have been found to be highly heterogeneous and context dependent (Condit 2010a). Attitudes are generally unfavorable when genetic testing is perceived to be utilized in a way that changes the 'natural order' of things (e.g., such as preimplantation genetic tests for IQ or life expectancy (Condit 2010a). In contrast, genetic testing is seen as favorable when its purpose is finding better pharmacological treatments or detecting of childhood fatal diseases, while attitudes were less positive for the prediction of adult-onset diseases. In the area of mental health, people' attitudes toward predictive testing have been found to depend on the availability of effective prophylactic interventions, and the potential negative consequences of test results, such as discrimination or individuals not coping with the burden of feeling 'doomed' by their genes (Laegsgaard et al. 2009, Lawrence and Appelbaum 2011).

The literature surrounding intentions to undergo genetic testing is also heterogeneous. A recent survey of 5405 participants from Russia, the UK and USA, shows that more than 80% of participants would consider undergoing genetic testing if that meant having access to improved health care (Chapman et al. 2018). However, Smerecnik et al. (2011) found that around 40% of a sample of smokers did not intend to undergo a genetic test to determine whether they were genetically susceptible to smoking addiction, or which smoking cessation treatment would be likely to be most effective for them. Lent et al. (2017) surveyed 700 US army veterans about their attitudes on genetic testing for post-traumatic stress disorder and alcohol dependency and found that 58.6% of the participants reported not wanting to know about their genetic results before, or after, deployment. On the other hand, studies of individuals that already have undergone genetic testing show that, for example, women diagnosed with breast cancer who had undergone *BRCA1/2* testing were satisfied with receiving a genetic risk profile based on common genetic variants and felt that it validated their past preventive health behavior (Young et al. 2017).

While we hope that as the public learns more about genetics, misinterpretations of genetic research will be reduced, the relationship between literacy and attitudes towards socio-scientific issues is not straightforward. This is demonstrated by the lack of association between cognitive proficiency and concern with climate change (Kahan 2015; Kahan et al. 2012), and the weak correlation between genetic literacy and deterministic thinking (Chapman et al. 2018). Moreover, providing factual information about genetically modified organisms at best results in small positive attitudinal changes (Druckman and Bolsen 2011; Frewer et al. 2003), but at worst results in negative backlash (Frewer 2003). Closer to the field of behavior genetics, higher levels of genetic knowledge have variously been reported to lead to more polarized attitudes toward genetic testing (Jallinjoa and Aro 2000) or not influence attitudes towards genetics at all (Henneman et al. 2006). To summarize, while improving genetic literacy is important, simply increasing knowledge may prove fruitless if we do not consider how people learn about sensitive scientific topics, and why they are sometimes resistant to specific arguments. In addition, in some cases even the messages coming from researchers are misleading and promote essentialist interpretations (Dar-Nimrod 2012).

The deficit model of public understanding of science

Traditional science communication campaigns typically operate under several assumptions that have been shown to be inaccurate (Ahteensuu 2012; Bubela et al. 2009). The 'deficit model of public understanding of science' assumes: (i) the public is ignorant of science; (ii) the public has negative attitudes towards science and technology; (iii) ignorance is at the core of these negative attitudes, and, (iv) this can be rectified by one-way science communication, where scientists communicate the facts to non-scientists (Ahteensuu 2012). In other words, a deficit model assumes that people are rational thinkers who simply lack knowledge. On the contrary, insights from behavioral economics and psychology demonstrate that this is not the case (Cacioppo and Petty 1984; Kahneman 2003; Kunda 1990). People rely on mental shortcuts and simple explanations when they can, and are motivated thinkers influenced by their values, emotions, and interests. This means that people are not passive recipients of scientific knowledge, but rather engage with it in a motivated fashion, and genetics is no exception. In the next section, we outline the most common biases that influence how the public understand scientific information.

Heuristic and systematic processing of information

According to dual-process theories, human cognition is explained by two types of cognitive processes. These cognitive processes are *Type 1*, or *heuristic*, characterized by automaticity, unconsciousness, rapidness, belief-based and low effort; and *Type 2*, or *systematic*, conceptualized as controlled, conscious, slow and demanding high cognitive resources. Dual process theories postulate that when individuals are not motivated enough to invest the time and effort needed to analyze new evidence, they will resort to Type 1 processes. These processes may include implicit associations acquired from personal experience, automated behaviors, or even innate perceptual, attentional or language-related processes (see review by Evans 2008).

Dual-process theories emerged in the 1980s in the context of attitudinal change and persuasion research. Researchers wanted to look at how to best convey information to people, and understand why information was sometimes taken up, and sometimes discarded. Two of the most influential theories from this perspective were the elaboration likelihood model of persuasion (Cacioppo and Petty 1984) and the heuristic–systematic model of information processing (Chaiken et al. 1989). Both models argued that people deploy different cognitive processes when forming an opinion on something, or someone, depending on their motivation and ability to think carefully. According to dual-process theories, Type 2 processing is limited by working memory capacity, cognitive traits like need for cognition (Cacioppo et al. 1983) or closure (Webster and Kruglanski 1994), and by contextual variables (i.e., framing, time available). In the context of public understanding of socio-scientific issues, an over-reliance on Type 1 processes is considered the most plausible explanation for public controversy over climate change—people may be motivated to deny evidence of climate change, and rely on quick heuristics instead of careful engagement with evidence (Kahan 2015). We also expect motivation and types of cognitive processing to play an important role in the misunderstanding of behavioral genetic research, given that it has been shown that heuristic thinking is a plausible antecedent of psychological essentialism (Cimpian and Salomon 2014).

Cimpian and Salomon (2014) proposed that psychological essentialism could emerge partly from the intuitive knowledge provided by Type 1 processes. In particular, they proposed the existence of an 'inherence heuristic', a cognitive bias that makes people look for internal explanations of human behavior rather than external determinants. This heuristic bias towards internal explanations would gradually develop into fully elaborated essentialist stances, such as psychological essentialism. This phenomenon fits with the *fundamental attribution error* (i.e., which Cimpian and Salomon refer to as *correspondence bias*), a well-known phenomenon in the social psychological literature whereby people typically attribute others' (but not their own) behavior to stable, internal factors (Jones and Harris 1967; Ross 1977). More recently, Sutherland and Cimpian (2019) found empirical support for such a link between an inherence heuristic and the strength of essentialist beliefs in children.

In view of this, conceptualizing genetic essentialism as a cognitive bias would open the door to developing specific 'debiasing' algorithms to prevent essentialist interpretations of genetic explanations. A debiasing algorithm is a set of rules to be followed in order to reach an unbiased outcome. Such algorithms require both awareness about the biases and strategies to correct biased thinking, such as the rules presented by Kahneman (2012) to correct for regression to the mean in intuitive predictions. More examples of debiasing techniques in other areas are the proposal for debunking scientific myths by Lewandowsky et al. (2012), or the proposal to correct hindsight and confirmation biases in decision making in health care by Chapman and Elstein (2000). In a similar way, specific debiasing algorithms for genetic essentialism could be presented within news articles or information brochures. They may be as simple as an explicit description of our tendency to prefer internal explanations and how we mistakenly use genetics as token for this when explaining the behavior of others, or an algorithm to look for alternative explanations of other people's behavior, though this will require specific research to confirm. Becoming aware of such biases most likely would reduce the impact of genetic essentialism, as suggested by Heine et al. (2017). In addition, past research has shown that people engage in more essentialist thinking when pressed for time, multitasking, or as a function of cognitive traits such as cognitive ability, need for cognition, or need for closure, which is compatible with essentialist thinking emerging from heuristic thinking (Cimpian and Salomon 2014). Therefore, tailoring educational interventions to the context in which information will be processed (e.g., classroom *vs* online media), based on how much time learners would have available, framing and format of the content, or the influence of other heuristic biases, would likely increase the likelihood of a correct understanding of complex genetic information.

That said, Type 1 processes have been shown to be insufficient to explain disbelief and negative reactions to socio scientific issues (Kahan 2015). This is mainly because individuals are often personally invested when evaluating information about socio-scientific issues, and both scientific facts and personal values play a part (Kahan 2015; Nielsen 2012). Dissemination strategies that ignore beliefs and attitudes of the public about socio-scientific issues may not only fail (Ahteensuu 2012), but even backfire (Amin et al. 2017). Furthermore, in the context of human genetics, Suhay and Jayaratne (2012) found different levels of endorsement of genetic explanations of human characteristics (i.e., race, class, individual differences, and sexual orientation) as a function of political ideology. More recently, Morin-Chassé et al. (2017) reported that political liberals and conservatives respond to the same information about the genetics of racial differences in very different ways, with liberals more likely to explain racial inequality as being the result of the environment (e.g., discrimination) whereas conservatives were more likely to see inequality as the result of stable genetic differences. These results illustrate the fact that personal values and ideology can play a strong role in shaping how genetic information is understood by people. In order to explain this, science communication researchers use motivated cognition theories.

The role of attitudes and values when knowing about science

Motivated cognition, or motivated reasoning, occurs when reasoning (e.g., evaluating evidence, forming impressions or attitudes, making decisions, etc.) becomes biased due to a preference, or motivation, for a specific outcome (Kunda 1990). Theorists of motivated cognition broadly categorize reasoning processes in two categories: (i) unbiased, where the aim is to be accurate, and (ii) directional or biased, where the aim is to arrive at a specific conclusion. The most common motivations that could bias information processing are: (a) preservation of self-concept or being coherent with one's interests or beliefs (i.e., *defense* motivation), and (b) satisfying social pressures or evaluations in a given social context (i.e., *impression* motivation) (Chaiken et al. 1989, Chen et al. 1999). Signs of a directional processing of information are (i) selective use of information, (ii) use of inferential rules to support personal goals, and (iii) biased evaluation of evidence. Conversely, *accuracy*-motivated reasoning has been associated with more complex and careful analysis of information, and less susceptibility to fundamental attribution errors (Kunda 1990).

In the context of genetics, Keller (2005) argued that genetic essentialism was in fact a form of directional reasoning that serves the values and social goals of those who endorse it. As highlighted above, motivated cognition is proposed to explain different patterns of endorsement of genetic explanations of human characteristics (i.e., race, class, individual differences, and sexual orientation), in particular as a function of political ideology (Morin-Chassé et al. 2017; Suhay and Jayaratne 2012). We also expect motivated cognition to be at play when scholars deny any type of genetic influence on behavior (Barlow 2019; Pinker 2002; Sesardic 2005).

Personalized medicine approaches using polygenic risk scores to tailor interventions would also be expected to trigger defensive processing of information, given the potential of genetic risk to threaten users' views of themselves as capable and healthy (Etchegary and Perrier 2007; Kessels et al. 2010). In the broader context of socio-scientific issues, Kahan et al. (2012) proposed cultural cognition, a specific type of motivated cognition, as an explanatory mechanism for the increase of polarization about sensitive scientific issues (e.g., climate change). According to Kahan et al. (2012), individuals will tend to conform their views on the issue to those held by their peers despite their literacy levels, in order to secure their social position (i.e., impression motivation).

Integrating dual-process with motivated cognition

While dual-process theories address the problems associated with heuristic thinking, motivated cognition theories tackle directional and biased thinking when personal motives and social pressures are involved. Based on our review of the literature, it follows that science education interventions should be oriented to promote accuracy-motivated reasoning, prevent motivated directional reasoning, and enhance systematic processing of information. However, focusing on motivated cognition without addressing heuristic thinking or vice versa is likely to fall short. With the aim of finding a validated model that integrates both family theories in mind, we searched the existing literature and identified the work by Chaiken et al. (1989) to be the most suitable for this purpose given that it expressly models cognitive and motivational biases.

The heuristic–systematic model of information processing (Chaiken et al. 1989), originally developed as a persuasion theory, proposes that there is a continuum between purely heuristic processing and purely systematic processing, and that people prefer less effortful to more effortful judgements. Chaiken et al. (1989) also distinguish between level of motivation and direction of motivation. The level or intensity of motivation will determine the probability of systematic processing; depending on how important it is for the individual to be confident about the judgement (i.e., desired confidence), people will invest more or less cognitive resources to understanding. The direction of motivation, on the other hand, will predict if the information is judged evenhandedly (i.e., accuracy-motivated processing), or if it would be selectively attended to or scrutinized in an effort to satisfy personal goals (i.e., defense-motivated, impression-motivated processing). Consequently, different situations would lead to different combinations of bias-unbiased, heuristic-systematic, processing of information (for a more detailed explanation, see the comentary by Chen et al. 1999).

The heuristic–systematic model of information processing has already been applied to understanding responses to genetic counselling (Etchegary and Perrier 2007), and to the design of educational messages in the context of breast cancer risk (Hitt et al. 2016). People typically see themselves as healthy, so when presented with information about their risk to develop health conditions, this information is likely to threaten their self-image and generate anxiety. This would likely motivate a defensive processing of information, which could lead to avoidance or distortion of the information and, therefore, prevent them from using this information (Etchegary and Perrier 2007; Kessels et al. 2010). In addition, we argue that the heuristic–systematic model of information processing may also explain why people misunderstand, avoid, or selectively choose to accept genetic explanations of health and behavior (see also Smerecnik 2010). Self-serving use of heuristics and biased scrutiny of information could explain why people's endorsement of essentialist interpretations varies between behaviors.

To summarize, the heuristic–systematic model of information processing provides insight into the mechanisms and factors underlying biased reasoning. Yet, it does not suggest how to encourage realistic and long-lasting understandings of genetic research, especially when we expect the new learnings to be in conflict with those previously believed about genetics, or to be viewed negatively within our immediate social contexts. Therefore, in the final section of this paper, we propose Schein and Schein's elaboration of Kurt Lewin's original change theory (Lewin 1947; Schein and Schein 2017), as a way to integrate the heuristic–systematic model of information processing with planned change theories.

Planned change for improving understanding and uptake of behavioral genetics

To illustrate the need for integrating the heuristic–systematic model of information processing with planned change theories, we would like the reader to consider the two following scenarios:

> Scenario 1: In her review, Douthit (2006) highlighted three extended misconceptions within the context of psychiatric genetics: (i) genes generally produce inevitable outcomes; (ii) biological causes unequivocally equate to biological interventions; and (iii) the effects of genes are permanent. Following from this, an individual who shared these misunderstandings hearing about a new genetic study for a condition they have, would not only have to overcome their own anxiety and misconceptions around genetic influence on complex traits, but also interact with family, friends, or co-workers that hold such misconceptions as well.
>
> Scenario 2: The genetic basis of human psychology has been the object of numerous academic disputes and social controversies for many decades now. Within the social sciences it is still challenging to suggest a genetic basis for human psychology given a perceived relationship between genetics a prejudice (Barlow 2019). Consequently, even if we succeed in explaining the use of polygenic scores for educational attainment as covariates or control variables in educational research (Lee et al. 2018) to a social scientist, we may find that such use is stigmatized and punished within their research area, thereby threatening the adoption process.

These two scenarios highlight key communication challenges facing behavioral genetics: previous knowledge and beliefs influence responses to new information, resistance to change can appear from the individual or from their social context, and individual learnings are compromised if social norms and expectations remain unchanged. Many of the interventions proposed to improve understanding and uptake of genetic research have focused on providing accurate information about genetics. In the examples above, however, this approach to genetic literacy would prove insufficient if personal motives, values, cognitive biases, and social context are not considered. For these reasons, we believe that Schein and Schein's approach to planned change is appropriate to understand how to responsibly explain and encourage uptake of behavioral genetics (Schein 1999; Schein and Schein 2017). This is the case, because the approach:

(a) explicitly models resistance to change due to conflict between previous values and ways of thinking and new

learnings, providing both ways to overcome such resistance and guide new learnings.
(b) includes the learner's social context and it provides mechanisms to guide change at a social level.

Broadly, planned change involves: characterizing the individual, group or community we want to influence (and their physical and social environment); intervening on the specific behavior or attitudes we want to change or promote; and evaluating the impact of that intervention (Hobman and Walker 2015). The change process proposed by Schein can be structured in three stages: (i) creating the motivation to change (*unfreezing* stage), learning new concepts, meanings, and standards (*change* stage), and consolidating new learnings (*refreezing* stage).

Stage 1: unfreezing

In this first stage, we aim to create motivation to learn, and to set the right conditions for that learning to occur. This stage begins with new information that disconfirms what we already know or believe, but if we do not have enough motivation to process such information, we will ignore, dismiss, or deny it. Conversely, if we care enough about what is being disconfirmed and we accept the new message as valid, it will motivate learning. Addressing this, the *jiu jitsu* approach to science communication (Hornsey and Fielding 2017) proposes that the goal of science communication should be to align with people's attitude roots (i.e., fears, ideologies and identities), thus reducing people's resistance to change in order to make people become more willing to accept scientific evidence. However, some learnings generate anxiety because they threaten, for example, our self-esteem or our group membership (i.e., sources for defensive and impression motivated reasoning, respectively). Learning anxiety is the main threat to unfreezing. This learning anxiety produces resistance to change and potentially leads to motivated reasoning, either heuristic or systematic, depending on situational variables including: time pressure, the perceived need to be accountable for one's judgments, and perceived amount of information needed to make a decision (Etchegary and Perrier 2007). Therefore, a key goal during this stage is to provide a safe learning environment that helps overcoming learning anxiety, via facilitating active learning, involving families or colleagues of the learner, or providing support groups where learning problems can be aired and discussed (a list of strategies for reducing learning anxiety can be found in Schein and Schein 2017).

In the context of behavioral genetics, disconfirmation would occur when we face new information that challenges what we knew or believed about genetics. Drawing on the available literature, some of the expected barriers to unfreezing are: insufficient genetic literacy, mixed attitudes towards behavioral genetics research and its applications, and cognitive biases. For a summary of the key components of the unfreezing stage, including related research questions in the context of behavioral genetics, see Box 1.

Box 1: key components of the *unfreezing* stage Intervention goals at this stage:

1 Boost motivation for the topic.
2. Promote disconfirmation (i.e., need to review our knowledge or attitudes).
3. Identify sources of learning anxiety and resistance to change.
4. Create a safe learning environment.

Research questions:

- What is the public motivated to know about genetics?
- What is the public not motivated to know about genetics that would be useful for them to know? How do we motivate them to learn about it?
- What values and attitudes of specific communities are in conflict with genetic literacy or specific genetics content?
- What topics trigger anxiety in the learner and how do we provide a safe learning environment?

Stage 2: change

When people manage to unfreeze, and are open to new information, they can *change* their attitudes, opinions, or knowledge base about a topic. For Schein and Schein (2017), change always requires a process of cognitive restructuring, which involves: (i) semantic redefinition (learning new words or terminology); (ii) cognitive broadening (expanding our previous theories about how something works); and (iii) setting up new standards or values. We consider that both semantic redefinition and cognitive broadening are systematic thinking processes. Therefore, our communication strategy must allow the learner to engage in this type of thinking, in the line of the work by Donovan et al. (2019). We also need to keep managing the motivations at play identified in the previous stage, in order to prevent directional reasoning and support accuracy-motivated processing of information. Finally, setting up new standards or values involves not just the learner, but also their community. People can strategically accept or discount information based on whether their social group does (Kahan et al. 2012) as noted in Scenario 2 above. For a summary of the change stage, and research questions related to it, see Box 2 below.

Box 2: key components of the *change* stage Intervention goals at this stage:

1 Enhance systematic processing of information.
2. Tackle motivated or biased reasoning (i.e., defensive and/or impression motivation).
3. Provide new concepts and definitions about our topic to the learner that are understandable and can be integrated with previous knowledge and attitudinal background.

Research questions:

- What are the strengths and weaknesses do different communication formats have for enhancing systematic processing of information (e.g., online articles, podcasts, classroom).
- What triggers defensive or impression motivation in specific communities when learning about genetics?
- What social norms, values, or practices (specific to the learners' context) make learning something a disadvantage?

Stage 3: refreezing

Refreezing is the last stage of the planned change process. The desired outcome of this stage is for new learnings to be incorporated and maintained by the learner. The main challenge at this stage is incompatibility between new knowledge and (i) the existing knowledge system of the learner, as well as (ii) the existing social norms and practices of the learner's community. New learnings must be compatible with who we are and what we already know (i.e., personal refreezing), as well as compatible with what is valued and believed by our group of reference (i.e., relational refreezing). An incompatible new learning would be perceived as disconfirming information and would restart the change process again (Schein 1999; Schein and Schein 2017). Investigating this last stage will involve assessing the impact of the change process. For this, we would rely on intervention-based experiments, pre-post and longitudinal studies, and multiple metrics based on the goals set before the beginning of the intervention (Hobman and Walker 2015). The recently published work by Donovan et al. (2019) is a perfect example of integrating heuristic thinking and motivated cognition in a human genetics education program. They were able to teach scientifically accurate information about genetic differences within and between ethnic groups, effectively reducing prejudice with no evidence of a backlash effect. In order to do that, they explicitly considered (a) the appropriate level of complexity to be for their audience, (b) the need to enhance systematic processing of information, (c) the role of personal values when learning about genetics. For other topics in behavioral genetics, we would need to rely on literature reviews, surveys, interviews and focus groups to identify educational needs and points of conflict between genetic content and prior knowledge and values. To conclude, we can insist on teaching the public about the nuances of heritability, polygenicity, gene-environment correlation and interaction, or biological pathways, but if we disregard external pressures when learning about genetics, it is unlikely that complex, reasoned knowledge of complex trait genetics will last. A summary of the main features of the refreezing stage and examples of research questions can be found in Box 3.

Box 3: key components of the *refreezing* stage Intervention goals at this stage:

1 Compatibility between personal beliefs and new knowledge.
2. Compatibility between ongoing relationships and new knowledge.

Research questions:

- How long will new learnings about complex genomics last? Does it differ depending on the trait? How do specific values or personal experiences influence refreezing?
- What public policies, moral values or social practices influence acceptance of specific genetic findings?
- Are there enough policies and legislations in effect to protect the public against misuse or of genetic research?

Conclusion

Tackling the factors leading to simplified and biased processing of information may greatly improve the understanding of behavioral genetics, and bridge the divide between researchers and the public. This means that accurate dissemination of scientific information about genetics requires scientists to consider and engage in corrective processes, and work towards communicating their findings as accessibly and accurately as possible.

We acknowledge that this review is narrative rather than systematic and as such not exhaustive. However, we suggest that a narrative literature review facilitates the task of conveying studies and perspectives from different fields, which often make use of different terminology that can hinder developing a clear question for a systematic review. Indeed, our literature review reveals that many researchers are actively working to understand how cognitive biases and motivated reasoning are shaping uptake of genetic information (see Donovan et al. 2019). The goal of the present review is to summarize this work, and introduce dual-process, motivated cognition, and planned social change models to a wider audience in order to aid communication strategies in behavioral genetics.

We suggest that combining a planned change model with the heuristic–systematic model of information processing will provide a wider perspective on public understanding of socio-scientific issues, and a solid framework for current work in dissemination of behavioral genetic research, following recent trends in science communication in other areas such as climate change or vaccine hesitancy (Amin et al. 2017; Bubela et al. 2009; Kahan et al. 2012). In addition, another advantage of Schein's planned change model is that it is not limited to any specific community, research topic, nor to individuals with specific levels of literacy or other characteristics. On the contrary, these models are broadly applicable across fields and can be used to understand how different communities learn about behavior genetics (i.e., lay public, journalists, health professionals, scientists). Finally, there are good reasons to use the present theories to explain why people might find it difficult to understand contemporary genetic research, but there are many models that have addressed these problems, and it is not our intention to set them over the others. The main goal of the present review was to stress the need for more complex psychological theories to improve science communication in the field, and move away from the deficit model of understanding and one-way literacy campaigns, where we expect people outside this specific research community to understand genetic findings in the same way that we do.

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Compliance with ethical standards

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