Please consult the journal version at Thinius, Alex, and Rose Trappes. Forthcoming. “Sex Traits and Individual Differences: Stabilising and Destabilising Binary Categories in Biological Practice.” *The British Journal for the Philosophy of Science.* <https://doi.org/10.1086/731829> .

**Sex Traits and Individual Differences: Stabilising and Destabilising Binary Categories in Biological Practice**

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**Abstract:** Sex is often thought of as a straightforwardly binary categorical variable. Yet there is considerable variation in would-be sex traits; from genitals and hormones to morphology, neurology and behaviour, there is rarely if ever a categorical binary. We introduce a strategy that researchers use to deal with this variation: Individualising Variation (IV). IV involves treating non-binary and gradual variation as idiosyncratic, as individual differences rather than sex-based differences. Using the contrasting cases of sex identification in field ornithology and the debate about sex differences in neuroscience, we illustrate IV and investigate its epistemic and conceptual consequences. We argue that IV stabilises the ontological picture of sex as categorical and binary. While IV can be an epistemically benign research strategy in some cases, we argue that it can also be epistemically detrimental. This is because of its ability to mask evidence that would otherwise challenge related assumptions about the phenomenon of interest, such as what sexes are and what they look like. We also identify an alternative strategy, De-individualising Variation, which works against IV and helps life scientists recognise variation beyond categorical binaries.

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1. **Introduction**

Decades of feminist research has taught us that variation is rife when it comes to sex (Roughgarden [2004]; Voß [2010]; Fausto-Sterling [2012], [2020]; Richardson [2013]). Scientists are constantly dealing with variation in the would-be sex traits of the organisms they encounter; from genitals and hormones to morphology, neurology and behaviour, there is rarely if ever a categorical binary. Yet many concepts and definitions of sex in the life sciences recognise just two sex categories, with individuals being ascribed one of those two categories. How do life science researchers construct sex as binary and categorical in the face of variation?

In this article we introduce one main strategy for stabilising sex as a categorical binary: the strategy of *individualising variation* (IV). In brief, IV involves excluding variation from a phenomenon—in this case, sex—by considering it to be a matter of idiosyncrasies or individual differences, not a part of the phenomenon itself. IV is a kind of *varipraxis*, that is, a way of identifying and articulating different forms of variation (Lowe and Ingram [2023]). We believe that IV operates as a general strategy across the life sciences that stabilises phenomena and categories in the face of variation. Nevertheless, we focus here on the distinctive and important ways that IV plays out in the case of sex. Using an example from ornithological field guides, we argue that IV stabilises the picture of sex as binary and categorical.

IV is a common epistemic strategy, but it is not the only way to deal with variation. By looking at the example of the ‘brain sex’ debate about whether there are distinctly male and female brains, we identify a contrasting strategy, which we call *de-individualising variation* (DV). DV involves recognising non-binary, non-categorical variation as inherent to sex. It thereby destabilises a common ontological picture of sex as binary and categorical. Recognising DV in the brain sex debate also indicates that IV can have epistemically detrimental consequences. Specifically, we argue that IV can mask evidence that variation is not idiosyncratic but is rather part of the phenomenon itself. This suggests that IV can play an immunising function, maintaining an ontological picture—in our cases, that the phenomenon of sex is binary and categorical—by suppressing anomalies and counter-evidence. Researchers should therefore be wary of employing IV uncritically, especially when it comes to epistemically, ethically, and politically fraught cases like sex.

In line with recent work on sex (Richardson [2022]; Evron [2023]), and on other scientific concepts (Brigandt [2012]; Feest and Steinle [2012]), we take a practice-based approach to analysing sex by attending to how it is operationalised in practices such as observation, experimentation, and modelling. In this context, we describe and analyse IV and DV as epistemic strategies in research practice, similar to standard approaches to social structural explanation (Haslanger [2016]). In this sense, we abstract away from questions of the intentionality of scientists and investigate instead the structure and implications of scientific practice (see section three).

In our case studies, we focus especially on life sciences in which human and non-human animals play a prominent role, such as animal ecology, human biology, biomedicine, and public health. Some biologists in these fields do not subscribe to a binary, categorical view of sex; researchers studying hermaphroditic fish, for instance, may treat the sex of individuals as a six-valued variable. Nevertheless, binary and categorical sex is pervasive in many practices throughout the life sciences, and it is these practices which are our focus.

Our analysis will feed into the recent smattering of debate in philosophy of biology about the concept of sex (Franklin-Hall [2021]; Khalidi [2021]; Richardson [2022]; Evron [2023]; Rifkin and Garson [2023]; Griffiths [Unpublished]) and, ultimately, to broader discussions in feminist philosophy and gender studies about the concept of sex. By bringing to light the dual epistemic strategies of IV and DV, we also contribute to the broader understanding of how scientists identify and constitute research phenomena in the face of complexity and variation (Woodward [2010b]; Feest [2017]).

We begin in section two by introducing how sex features in life sciences research and setting out the challenges and debates related to defining sex as binary and categorical despite the existence of greater variation. In section three, we develop an account of IV, and in section four we exemplify it at work for stabilising conceptualisations of sex with an example from bird identification. In section five, we complicate this account by considering the brain sex debate, which we use to highlight the DV strategy. Finally, in section six we close by considering the implications of recognising IV and DV for how we should understand sex in life sciences research.

1. **Sex in the Life Sciences**

References to sex abound in the life sciences, especially those life sciences in which human and non-human animals play a prominent role. Sometimes this is because sex is an object of research. For instance, evolutionary biologists study the evolution of sexual reproduction and sexual dimorphism, and developmental biologists investigate the development of sexual morphology. Even when it’s not an object of research, though, sex frequently appears in the research questions, hypotheses, methods, theories, and findings of life scientists. For instance, animal behaviour researchers often hypothesise that females and males of a species differ in behaviour (e.g., Tarka *et al.* [2018]; Harrison *et al.* [2022]), and biomedical researchers frequently quantify and report the sex distribution of their study populations in studies on Alzheimer’s Disease (e.g., Mielke *et al.* [2014]; Harms *et al.* [2022]; Castro-Aldrete *et al.* [2023]).

In these latter cases, sex is treated as an explanatory*,* predictor*,* orindependentvariable. That is, sex is treated as a difference between individuals that might explain, account for, predict, or influence the variation in some other phenomenon, such as behaviour or Alzheimer’s Disease. The importance of explanatory and predictor variables, including sex, might be familiar from basic statistics and everyday causal reasoning. On the one hand, a factor that explains variance in a phenomenon of interest may be a cause of that phenomenon. On the other, there may be mere correlation between some factor and the phenomenon of interest; using that factor as a predictor variable can be an effective way to reduce variation that disguises potential patterns in the phenomenon of interest.

Treating sex as an explanatory or predictor variable is very widespread. Sometimes researchers have justifiable reasons for this practice. Theoretical reasons or evidence from past studies from relevantly similar systems can indicate that sex is associated with a phenomenon of interest, and that it can thereby explain variation in that phenomenon. For instance, theoretical modelling may have shown that having more males than females in a population, provided certain conditions obtain, affects population dynamics. So if you want to study population dynamics of a certain study population in which those conditions obtain, using sex distribution as an independent variable makes sense: something about sex (however this is defined in the study at hand) might be a causal factor in the study population, or it might help reveal other interesting patterns in your data.

An additional reason for the widespread inclusion of sex as a biological variable (SABV) in individual research designs and practices is due to science policy decisions in national and international funding agencies or incentive structures in corporate funding. For example, one of the largest biomedical funding agencies in the world, the National Institutes of Health (NIH) of the United States of America, has a SABV mandate for funding applications in biomedical research (National Institutes of Health [2017]). This mandate has led to an increase in the number of studies using sex as a variable (Arnegard *et al.* [2020]). The epistemic benefits, limitations, and risks of this policy and its implementation in research practice are subject to considerable debate (Tannenbaum *et al.* [2016]; Garcia-Sifuentes and Maney [2021]; Nielsen *et al.* [2021]; Waltz *et al.* [2021]; DiMarco *et al.* [2022]; Maney *et al.* [2023]). Regardless, SABV directives add to the variety of reasons why researchers include sex as a variable in biological research and can influence how and why specific pictures of sex may change or persist in research practice.

On the other hand, sex is sometimes used as an explanatory or predictor variable due to a form of generative entrenchment (Wimsatt [2007]; Trappes [2024]). For instance, large longitudinal datasets or multipurpose open datasets often include sex as a variable because it’s relevant to some investigated phenomena, even if it’s not relevant for all users of the dataset. Similarly, researchers sometimes build on past research findings of sex differences, without sufficient attention to relevant dissimilarities in study systems and research questions. Often, this is an effect of institutionalization and the formation of traditions in research: researchers learn from and build on the methods and design of earlier studies, and these become instituted as standards, disciplinary conventions, and repertoires (Ankeny and Leonelli [2016]). Sex may be included because it is part of an institutionalised package of methods and variables, or because it is passed on as a standard variable that one always expects to be involved. In addition, scientific practice is entangled with broader socio-cultural developments that can contribute to the persistence of a ‘zombie fact’: the maintenance of claims, variables, and methods despite insufficient evidence or concrete counter-evidence (Jordan-Young and Karkazis [2019]; Zhao *et al.* [2023]). Finally, unjustified preconceptions of the nature and relevance of sex can persist in life science practices due to wide-spread methodological confusions about the use of sex variables. For example, across and sometimes within studies, predicted correlations are treated as evidence for causation (DuBois and Shattuck‐Heidorn [2021]). Another example is that ‘sex’ is (often tacitly) used as a proxy, for example, for occupation (DiMarco *et al.* [2022]).

Whether as a topic of research or as an explanatory or predictor variable, sex is often treated as both binary*—*involving two values, female and male—and categorical*—*rather than gradual or continuous. In other words, an individual or one or more of their traits is frequently seen as either female or male. And individuals (or traits) are seen as female or male categorically; that is, on this view, there are no amounts or degrees of sex. Notably, the binary and categorical conceptualisation of sex is often used when categorising not only individuals but also individuals’ phenotypic (or sometimes genomic) traits, such as colour patterns, gonads, hormone levels, or brain structure. The latter are generally called sex differences, sex-related traits or sex-correlated traits (Franklin-Hall [2021]).

The binary and categorical conceptualisation of sex has a long yet contested history. 19th and 20th century biology largely defined sex as a biological binary difference with reference to a varying list of traits or features and to reproductive functionality. The categorical approach to the binary definition of sex became dominant in the first half of the 20th century, which, arguably, was less driven by new insight in sexual differences than by its association with the then new Mendelian approaches to heredity (Richardson [2013], chapters 2–3). At least since 1900, however, there have been disputes about whether the sexes are indeed differentiated in a binary way at all, given available empirical evidence (Sigusch [2008]; Voß [2010], [2021]; Leck [2012]). In the phase after the establishment of the discipline of sexology, there were for instance ‘third sex’ and ‘continuum’ theories of sexual difference (Steakley [1997]; Mancini [2010]; Hirschfeld [2015]), developmentalist resolutions of the apparent puzzle (Freud [1989]; Mehlmann [2000]), as well as quasi-Platonist defenses of a substantial sexual binarity that is realised in mixed material manifestations (Weininger [1908]; Sengoopta [2000]). These early debates, and their incomplete resolution, demonstrate that a binary, let alone a binary categorical, definition of the sexes doesn’t go without saying.

There is by now ample evidence challenging the view that sex is binary and categorical in any straightforward sense. Especially—but not only—feminist and queer biologists and science studies researchers have pointed out that sex differences vary among sexually reproducing species (Roughgarden [2004]; Ah-King [2009]; Voß [2010], [2021]; Fausto-Sterling [2012], [2020]). As well as attention to taxonomic variation in sex-related traits (which traits are associated with sex and how they are so associated) there has also been increasing recognition of intraspecific or inter-individual variation in sex-related characteristics. Organisms in sexually reproducing species can have traits that cannot be classified as either male or female, as seen for intersexed individuals among humans. There is also considerable variation amongst individuals in many traits used for sex identification. For instance, morphological features like size and colour are used to assign sex in many species of fish; individuals can nevertheless vary along size and colour gradients. This raises the question of how life scientists make their binary categorical classification congruent with the variation they find in the field.

Renewed recognition of sex-related variation has reawakened the debate about how to define sex (Ainsworth [2015]; Richardson [2022]; Thinius [2024]). Several philosophers of biology take their cue from definitions of the sexes in terms of anisogamy, that is, differential gamete size (Roughgarden [2004], chapter 5; Goymann *et al.* [2023]). For instance, Khalidi suggests that animal sexes may be causal kinds, in which a binary and categorical difference in gamete size causes associations between gamete size and other morphological and behavioural traits (Khalidi [2021]). Somewhat similarly, Franklin-Hall has argued that animal sexes are developmental historical kinds, such that an individual animal counts as male or female depending on the evolutionary history of its reproductive developmental system (Franklin-Hall [2021]). On this account, all animal species share a ‘two-sex system’ traceable back to early anisogamous animal ancestors, but due to differing selection pressures and the long evolutionary history, there is great taxonomic variation in which traits are associated with sex and how these traits are distributed in a population. As another example of a recent philosophical definition based on anisogamy, Griffiths defines sex as regions of phenotypic space in which individuals implement distinct ‘gametic reproductive strategies’, such that ‘males make small gametes and females make large gametes’ (Griffiths [Unpublished], p. 4). On Griffiths’ view, in most species there are ‘only two biological sexes’ (Griffiths [Unpublished], p. 5): two gamete types and two corresponding regions of phenotypic space for individuals to occupy. Nevertheless, Griffiths argues that there can be many ways of being a particular sex (many points in each phenotypic region); moreover, depending on their traits, individuals can occupy both or neither of the sex-associated phenotypic regions—that is, individuals can have no assigned sex or can be hermaphroditic. As a final example of an anisogamy-based definition of sex, Rifkin and Garson recently developed a functional definition of animal sex, such that being of a particular sex is defined as having a body part with the function of producing a certain type of gamete (Rifkin and Garson [2023]).

Others argue for a multivariate and multimodal model of sex (McLaughlin *et al.* [2023]). According to this model, sex comprises multiple independent traits, including gametic, genetic, hormonal, anatomical, and behavioural traits, and these traits can have variable distributions of values within a population, rather than only binary categorical or bimodal distributions. In contrast, Richardson proposes a contextualist account of sex, arguing that different concepts of sex are suited to different research contexts (Richardson [2022]). On this account, sex-related biological variables vary among certain subclasses of individuals identified as relevant for a particular research context; these sex subclasses (and thus the sex-related variables) may be categorical or continuous, and there may be any number of relevant sex subclasses. Finally, still others take an eliminativist stance, arguing that sex is an imprecise and unnecessary proxy for other, more important variables or phenomena such as reproductive dimorphism (Evron [2023]; Watkins and DiMarco [2023]).

Thus, whereas definitions of sex as binary and categorical are common in biological research, more complex concepts and models of sex have arisen and persisted as alternatives and critical interventions. Rather than answer questions about whether sex is truly binary and categorical, or how best to define sex, we take a step back and ask how scientists enact and enforce conceptualisations of sex through their everyday research practices (Pape [2021]; Richardson [2022]; Evron [2023]). Specifically, we aim to investigate the epistemic practices through which binary and categorical conceptualisations of sex are stabilised in the face of variation in putative sex characteristics, such as genotype, genitals, brains, size, colour, or behaviour of an organism. How do life science researchers construct sex as binary and categorical in the face of variation?

1. **Stabilisation Through Individualising Variation**

Life scientists are constantly faced with variation in the phenomena they are studying or the variables they are using. Sex is not unique. In this section we introduce a general scientific strategy for dealing with variation, which we call *individualising variation*. In the next section, we return to sex and exemplify this strategy at work.

Canonically, scientists are interested in studying general patterns, types and categories, and regular, repeating phenomena. In particular, generality, simplicity and broad scope are key values in many scientific research contexts (Kuhn [1977]; Longino [1995]; Douglas [2013]; Potochnik [2017]). Scientists often value general and simple models or theories that have a broad scope and can thereby describe, explain, predict, or be used to intervene on many different instances. For instance, life sciences researchers search for general models or mechanistic explanations of disease transmission, ecological succession, or organism-environment interactions. These general models and explanations help to understand, explain, predict and, hopefully, intervene on and control a range of phenomena.

There are, of course, sciences that are interested in particularities and individuals. The historical sciences, such as archaeology or paleobiology, are interested in reconstructing actual historical sequences and causal relations (Wylie [2002]; Cleland [2011]; Buskell and Currie [2021]). Similarly, health sciences aim at diagnosing and treating particular individuals, and conservation biology involves addressing particular populations and ecosystems. However, even in these disciplines, generalisations play a role in supporting causal inferences and explanations, and many studies of individuals aim to develop claims about patterns or relations that apply across many instances (Woodward [2010a]; Ankeny [2014]; Page [2021]). So even in disciplines concerned with particularities, general knowledge is still an important goal.

In addition to their epistemic values and goals, scientists’ methods also drive them to look at phenomena that are regular and general. Measurement, experimentation, and statistical inferences all require multiple instances of a phenomenon (Trappes *et al.* [unpublished]). This is important for dealing with error and noise. By observing multiple instances, researchers are able to isolate the real phenomenon or causal relation from the fluctuations introduced by measuring instruments or extraneous causal factors (Bogen and Woodward [1988]; Cartwright [1989]; Woodward [2004], [2010b]; Chang and Cartwright [2008]). Hence, basic theories of measurement, experimentation and statistics mean that researchers must study phenomena that can be repeatedly instantiated across individuals or over time. This methodological assumption of stable and general phenomena also extends across studies, as witnessed in recent debates about the failures of replication in several disciplines (Leonelli [2018]; Fidler and Wilcox [2021]; Feest [2022]).

The epistemic constraints of standard research practices join epistemic values in leading researchers to focus on general, repeatable phenomena. What does this mean for variation? Most scientists are aware that there is real variation in the phenomena they observe and experiment on, and variation is recognised as crucial to key biological processes such as evolution (Mayr [2006]). Some scientists even take variation as a target of research. For instance, cognitive scientists have recently begun to study individual differences in cognition (Ward [2020], [2022]), and behavioural ecologists have started investigating individual differences in behaviour and ecological relations (see below). Moreover, taxonomists and population geneticists have long taken variation as a primary target of their research (Lowe and Ingram [2023]). All of these researchers face considerable challenges that require methodological innovations to discriminate amongst patterns and sources of variation, distinguish genuine and important variation between individuals from error and noise, identify phenomena, and develop generalisable knowledge (Ward [2020], [2022], [2023]; Lowe and Ingram [2023]; Trappes *et al.* [unpublished]).

However, with their goal of general knowledge, most life science researchers pay attention to variation only insofar as it can be categorised and subject to generalisations. Moreover, the constraints of standard methods mean that variation gets lumped together with measurement error, individual idiosyncrasies, and causes other than the causal relation of interest. As a consequence, we see a pattern where variation is typically excluded from target phenomena and explanatory categories. It is within this epistemic landscape that the strategy of *individualising variation (IV)* operates.

**Individualising Variation (IV)** is the strategy of attributing observed variation to individual idiosyncrasies, as distinct from the phenomenon or category of interest.

In other words, IV takes variation that neither fits into recognised categories nor associates with important phenomena, and attributes it to individual idiosyncrasies. Together with measurement error and extraneous causes, these idiosyncrasies are excluded from the phenomena and categories that scientists operate with. IV thereby reinforces the stability and generality of phenomena and categories in the life sciences. This conforms with both scientists’ values and goals and the epistemic constraints of standard research practices.

Like other practices for dealing with variation in the life sciences, IV is involved in identifying and articulating forms of variation. IV is therefore a kind of *varipraxis*, a term which James Lowe and David Ingram recently coined to refer to ‘the set of practices involved in the apprehension, measurement, investigation and analysis of different forms of variation.’ (Lowe and Ingram [2023], p. 3). And, like other varipraxes, IV involves distinct ontological commitments that are entangled with methodological and epistemic features.

In this paper, we understand IV (and de-individualising variation, DV; see section five), including their causal effects on ontological pictures, as structural features of some epistemic social practices, which are specific ‘patterns of learned behavior’ (Haslanger [2018], p. 245). Identifying these patterns contributes to structural explanations of ‘the behavior of the individual given their place in a structure [. . .] [B]y identifying the structure within which action occurs, we can also call for an explanation of the existence and shape of the structure’ (Haslanger [2016], pp. 128–9). Despite improving the readability of our paper with standard shorthand intentionalist language of ‘using’ or ‘employing’ IV (and DV) as ‘strategies’, individual researchers may or may not intentionally draw on IV (or DV); and they may or may not want to stabilise a binary and categorical ontological picture.

1. **Individualising Variation Stabilises Sex as Binary and Categorical**

IV plays a role across the life sciences for many phenomena and categories. But we are particularly interested in how it operates to stabilise the picture of sex as binary and categorical. In this section we illustrate the strategy of individualising variation at work in animal ecology, using an example from ornithological field guides. This also paves the way to start thinking about alternative ways of dealing with sex-related variation in the life sciences.

In animal ecology, sex differences join a number of other prominent differences, including age and morphological type, as important explanatory variables for a wide range of behavioural and ecological phenomena. For instance, sex, age and morph may partly explain or predict resource use, such as the quantities of different food sources consumed by each animal. However, these categories (and other identified causal factors, such as experimental treatments) do not explain or predict all variation amongst individuals. The remaining variation, so-called *unexplained* *variation*, is attributed to individual idiosyncrasy, measurement error, and chance fluctuations. In particular, behavioural ecologists define what they call *individual differences* as variation that is not explained or predicted by sex, age and morphological type (Bolnick *et al.* [2003]; Trappes [2022]). With definitions like this, individual idiosyncrasies simply cannot be sex differences, even if they are in key sex-identification traits such as morphology or behaviour.

Take field identification guides as an example. Field guides generally provide information about morphological and behavioural characteristics that are distinctive for particular species, age classes, and sexes. This kind of information is important. In particular, identifying the sex of individuals in the field is instrumental for biologists to take sex as an object of research or explanatory or predictor variable. Moreover, birds serve as paradigmatic cases for studying sexual selection in evolutionary biology, adding additional theoretical interest in sex-based variation in traits such as plumage and behaviour.

Given the purpose of field guides to aid ready identification through picking out diagnostic features, characteristics are described in text and represented in images in a way that emphasises the distinctness of the sexes (or age classes, or species). Field guides do occasionally acknowledge variation in sex-distinguishing characteristics. However, they attribute this variation to individual idiosyncrasies (or to age class or morphological type), rather than to sex. In doing so, they engage the IV strategy. As we illustrate below, IV works to exclude gradual variation from sex, ensuring that sex is treated as a categorical variable. In addition, IV excludes variation that lacks a strong bimodal distribution, ensuring that sex is treated as binary. As such, in these cases, IV stabilises sex as both binary and categorical.

To illustrate, consider the page on the hooded warbler (*Setophaga citrina*) in *Birds of the World*, a leading online bird guide developed by the Cornell Lab of Ornithology in collaboration with ornithologists and birdwatchers around the world (Mumme *et al.* [2023]).[[1]](#footnote-1) The field guide represents females and males separately, showing the male in full profile and the head only of the female (see illustrations in Mumme *et al.* [2023]). This depiction indicates, first of all, that there are two types to be expected in the field. Secondly, it illustrates the female’s conspicuous absence of a full black hood around its face. The accompanying text also highlights the distinctive black hood of the males.

In depicting and describing female hooded warblers via the absence of a feature ascribed to males (and to the whole species via the common name), *Birds of the World* conforms to representational conventions in ornithology. As Van de Pitte ([1998], p. 24) writes of these conventions, ‘The subliminal message is that to be female is derivative in relation to the male [. . .] That is the core of sexism.’ More pertinent for our purposes here, however, is that *Birds of the World* also describes the considerable individual variation of the female’s hood (or lack thereof):

The male has a distinctive black hood that it acquires when it is about 30 days old and retains the rest of its life. The female, however, shows considerable age-related and individual variation in the extent of the black hood. The first-year female has few or no black feathers on its head and neck, but older females vary tremendously, from birds lacking black and resembling the young female to birds with a complete black hood that is almost identical to that worn by the male; the adaptive significance of such wide individual variation in female plumage remains unknown. (Mumme *et al.* [2023])

This guide performs the IV strategy: male plumage involves having a black hood and female plumage doesn’t; although in actual fact some females do have a black hood, this is treated as individual variation in an otherwise sex-distinguishing characteristic.

The guide also describes another morphological trait of the hooded warbler, the amount of white in the outer tail feathers. In contrast to the black hood trait, tail feather whiteness is not named as a diagnostic feature for sex identification. In somewhat technical ornithological language, the guide explains:

Both sexes show considerable variation among individuals in the extent of white in the outer rectrices and this variation persists even after controlling for differences in tail length and age [. . .] The male averages slightly more white than the female, and birds in definitive basic plumage average slightly more white than those in formative plumage, but tail length, sex, and age collectively explain only about 17% of the inter-individual variation in tail white [. . .] Extensive individual variation in the amount of white in the tail is of interest because of the role the white tail spots play in foraging behavior. (Mumme *et al.* [2023])

In other words, although there is a statistically significant difference between the sexes in the amount of white in their tails, sex still explains or predicts very little of the overall variation in tail whiteness. As such, variation in tail feather whiteness is almost entirely attributable to individual variation, not sex or age. This highly variable characteristic is then excluded from the sex-distinguishing characteristics (the black hood and the intensity of green plumage colour) and attributed instead to individual variation.

The treatment of tail feather whiteness is therefore also an instance of the IV strategy. Like variation in the black hood trait, variation in tail feather whiteness is treated as a matter of individual idiosyncrasies—as individual differences rather than sex-based differences. Sex identification characteristics are thereby limited to more clearly dimorphic traits, to the exclusion of morphological traits that exhibit gradual variation and lack a strongly bimodal distribution. This helps to further shore up the conceptualisation of sex as binary and categorical.

In the introduction we mentioned that some biologists may make use of a more complex understanding of sex. We do not consider these sorts of examples here, focusing instead on areas of research where sex is typically treated as binary and categorical. However, this does not mean that IV does not also operate for these more complex pictures of sex. In particular, IV seems relevant for constructing any sort of categorical sex variable, even when many-valued. For instance, categorising individual fish as one of several sexes based on size and colouration, might involve distinguishing sex-based variation from individual variation in those traits. On the other hand, these sorts of cases may involve other strategies for dealing with variation (such as de-individualising variation; see below). The generalisability of IV to non-binary sex concepts is therefore something that requires further research.

1. **De-Individualising Variation, Destabilising Sex as a Binary Category**

We have argued so far that IV stabilises the binary and categorical picture of sex. In this section we identify an alternative way in which life science researchers approach variation in would-be sex traits: *de-individualizing variation* (DV). We introduce this strategy by considering the so-called brain sex debate. Recent developments in this debate exemplify DV, with individual differences being incorporated into the phenomenon of interest rather than being excluded. We also argue that DV sheds new light on the epistemic consequences of IV.

The *brain sex* or neurosexism debate concerns the existence of distinctly male and female brains (Fine [2010]; Jordan-Young and Karkazis [2019]). At stake in this scientific debate is whether human brains are dimorphic in relation to categorical and binarily understood sex: whether there is a male and a female brain. The brain sex debate is entangled with larger racist, ableist, and misogynist socio-historical contexts, with funding structures and science policy, and with the nature/nurture debate. For our discussion, however, we focus on how the issue of categorical binarity is renegotiated in this debate.

Many brain researchers (for example, neuroscientists, cognitive scientists, and psychologists) argue that there are significant differences between the brains of human males and females. Call this the brain sex thesis: that human males and females exhibit significant structural differences in different areas of the brain. Hence the widespread talk of male and female phenotypes of human brains, or sexual dimorphism in brain phenotypes. The brain sex thesis is in line with some scientists’ hypotheses and theories concerning evolutionary causes and effects of dimorphism in human brains (cf. DeCasien *et al.* [2022]). Yet many other brain researchers argue that the brain sex thesis does not hold. These brain researchers and their collaborators in adjacent disciplines–which we call *brain sex critical* researchers–argue that average differences do not amount to dimorphism of male and female brains (Eliot *et al.* [2021]).

Joel ([2012]) introduces a concept of 3Gsex that helps when characterising brain sex critical positions. On this concept, there are four recognised sex types: 3Gmales, 3Gfemales, plus two intersex types (the latter occurring in an estimated 1% of humans). 3Gmales and 3Gfemales are those individuals whose sex is assigned as male or female, respectively, concordantly along three definitional dimensions: genes, gonads, and genitals (Joel [2012]). Although 3Gsex would benefit from critical examination, we focus here on its methodological function for the brain sex debate: 3Gsex defines sex groups without reference to brain characteristics.

Brain sex critical researchers highlight individual variation in the relationship between individual brains and group-level correlations. Joel argues that slight statistical differences between brains of 3Gmales and 3Gfemales at the group level translate in a ‘mosaic’ way to individual brains. On the one hand, two traits, say larger overall brain size and size of the hypothalamus, may be slightly more common among 3Gmales than among 3Gfemales. On the other, any given individual can have a combination of brain traits associated with both 3Gmales and 3Gfemales (and, of course, traits that are not correlated with 3Gsex at all). For instance, an individual 3Gfemale may have, say, an overall brain size more associated with 3Gmales, combined with a hypothalamus that is more associated with 3Gfemales (Joel [2012], [2021]; Joel *et al.* [2015], [2018]; Joel and Vikhanski [2019]).

In fact, brain sex critical researchers argue that this mosaicism in brain traits is near universal in the human population (Rippon *et al.* [2014]; Eliot *et al.* [2021]). They argue that 3Gmales have many brain traits that are more associated with 3Gfemales, and likewise for 3Gfemales and 3Gmale-associated traits. Moreover, only few individual 3Gmales will have all or most 3Gmale-associated brain traits, and respectively for 3Gfemales. As Rippon et al. write, ‘an individual does not have a uniformly “female” or “male” brain, but the “male” form (as statistically defined) in some areas and the “female” form in others, and in ways that differ across individuals [. . .] An implication of this mosaicism is that specific brain areas that are labeled as having a “female” or “male” phenotype can only be detected through group-level statistical comparisons’ (Rippon *et al.* [2014], p. 3).

Although they agree on individual variation, sex critical researchers differ in their conceptualisation of group-level correlations. In this, we see DV operating with different effects for the categorical and the binary aspects of brain sex.

For example, Rippon et al. highlight individual differences as part of the picture of how brains relate to sex: putative sexed ‘forms’ at the group level do not imply that individuals realize them. In this case DV challenges to some extent the categorical conceptualization of brain-sex, especially when it comes to the brains of individuals. Language of male and female types and forms is open to both gradual and categorical interpretations. Nevertheless, although the brains of individual 3Gmales and 3Gfemales are pictured not as categorically but as typically and gradually different, the statistically defined male and female forms or types bring back a categorical picture. Moreover, these brain sex critical researchers still appear to maintain a binary view of sex-related brain types.

In other research, DV challenges both the categorical and to some extent also the binary approach to brain sex. For example, in distinction to concepts of form and type, Joel introduces the notions of ‘male end’ and ‘female end’ (Joel [2012], [2021]). This move uses individual variation to counter a categorical interpretation of ‘statistically defined’ sexed brain types or forms. Moreover, by conceptualising intersex as ‘intermediate’ space between male-end and female-end correlated brain traits, Joel’s account disrupts a strictly binary conceptualisation of sex. However, it is an open question whether and to what extent ‘intermediate’, as a derived space between male-end and female-end, effectively disrupts a binary conception of sex in the larger research context.

Some brain sex critical researchers use DV in different ways with the effect of destabilising both the binary and the categorical characterisation of brain sex. They point out that within studies, correlations at the group-level are not sufficiently dimorphic due to the overwhelming overlap between 3Gmales and 3Gfemales in brain patterns. For instance, inter alia referring to Joel’s work, Hyde et al. write that ‘the intermediate nucleus of the human hypothalamus is about twice as large, on average, in men compared with women, yet in approximately 30% of men, ﻿the size of this nucleus falls in the female-typical range’ (Hyde *et al.* [2019], p. 173). In this, treating individual variation as part of the phenomenon in question effectively puts pressure on the categorical picture. In addition, Eliot et al. ([2021]) argue that group-level correlations are not consistent enough across studies and populations to warrant a binary differentiation of human brains, whether categorical or gradual. They write, ‘a picture is emerging not of two brain types nor even a continuous gradient from masculine to feminine, but of a multidimensional “mosaic” of countless brain attributes that differ in unique patterns across all individuals’ (Eliot *et al.* [2021], p. 690). That is to say, the discussed brain sex critical researchers respond to the binary and categorical view of male and female brains with the alternative picture of individual mosaicism.

Sex critical researchers accept, thus, that there are slight group-level differences in particular cohorts, even if these do not amount to dimorphism. However, they argue in several ways that the individual variation in these correlations is a part of the phenomenon of sex-related differences in the brain, rather than being entirely attributable to measurement issues and merely idiosyncratic variation. Responding to a given picture of the putative general phenomenon of male and female phenotypes in the human brain, brain sex critical researchers propose an alternative picture of the phenomenon. This picture has a single type of brain, with varying correlations between brain patterns and 3Gsex at the cohort level, and individually varying mosaics.

We argue that this way of attending to individual differences represents an alternative epistemic strategy to IV—*de-individualising variation (DV)*. DV is an epistemic strategy that involves highlighting that some variation in the trait expression of individuals is a part of the general phenomenon in question.

**De-Individualising Variation (DV)** is the strategy of treating observed variation that could have been attributed to individual idiosyncrasies as instead variation in the phenomenon or category of interest.

In our case study of the brain sex debate, DV comes in view as an alternative to IV. Rather than distinguishing binary, categorical brain sex from individual idiosyncrasies or measurement error, brain sex critical researchers argue that brain sex just is a matter of an array of different individual mosaics. In essence, brain sex critical researchers argue that some individual variation that had been approached with IV belongs, instead, to the phenomenon in question. This effectively destabilises the picture of binary and categorical brain sex. DV was, however, performed in a variety of epistemic moves: sometimes, DV was involved in destabilising only the categorical picture of brain sex, leaving a binary view more or less unchallenged. In other cases, DV destabilised both the categorical and the binary aspects of the picture of brain sex.

Our case study has shown DV and IV in a dialectic relationship such that DV responds to IV. It is an open question if this is a unidirectional relationship, if IV can be a similarly effective response to DV in some cases, or if IV and DV occur only in a dialectic relationship. Regardless, DV can have epistemically beneficial effects. In our case study, this was visible in how DV challenges proponents of the brain sex thesis to improve their work and take more data into account. For example, DeCasien et al. ([2022]) directly respond to a paper that collects evidence and arguments against the brain sex thesis, including insights obtained through DV (Eliot *et al.* [2021]); DeCasien et al. aim for a limited stabilisation of the dimorphism claim, without being able to discard the counter-evidence.

One might be wondering which phenomenon these researchers are exactly talking about and if the phenomenon might have changed. Are brain sex critical researchers still talking about sex differences in the brain at all? We think it is plausible that the phenomenon might be shifting from sexed brains to brain pattern mosaics. In that sense, DV may be part of a repertoire of epistemic strategies through which researchers transform the research questions they ask and the phenomena they study in response to other elements of their practice, including new findings, technologies, epistemic values, and so on (Rheinberger [1997]; Kronfeldner [2015]; Feest [2017]). It might even come about that the phenomenon of brain sex ceases to be recognisable as such: that it, in a sense, dissolves under the weight of individual variation in brain attributes.

The dialectic way in which DV can be epistemically beneficial suggests that pursuing only IV can be epistemically detrimental. In the brain sex debate, DV involved researchers perceiving individual variation as anomalies for the brain sex thesis. This suggests that the earlier employment of IV regarding brain sex was masking and explaining away important counter-evidence. In other words, IV may have epistemically harmful effects by sidelining important counter-evidence to a dominant theory.

Further attention to the brain sex debate might highlight more examples of the epistemic utility of DV. For instance, the implementation of DV by brain sex critical researchers seems to foster more detailed etiological investigations, for instance into brain plasticity, or into interactions between people and their respective socio-historical, non-human, and inorganic environmental systems (Eliot *et al.* [2021]; Friedrichs and Kellmeyer [2022]). In our case study, DV also motivated a new picture to conceptualise the relationship between brains and the sexes, mobilizing the metaphor of the mosaic. However, other case studies may find other alternative pictures, models, metaphors, and concepts. We take this to show that performing DV does not only put pressure on a given ontological picture, but it can also open up the conceptual space for alternative pictures of a researched phenomenon.

So, IV is not the only way to approach individual variation and sex. DV offers an alternative that researchers can consider when faced with individual variation, one that offers distinctive epistemic benefits. Moreover, recognising DV has potential for painting alternative pictures of sex in life sciences research that are not necessarily binary and categorical.

DV is not the only alternative to IV, and DV and IV are not the only epistemic strategies to maintain or modify ontological pictures and conceptual set-ups to recognise phenomena in a research practice. For example, there are many techniques that aim at stabilising phenomena in experimental contexts, from physics to psychology (Hacking [1983]; Bogen and Woodward [1988]; Feest [2011]). In addition to introducing and maintaining pictures of phenomena, the development of experimental techniques can also lead to internal differentiation, break down, and retirement of scientific concepts (Haueis [2021]). Another relevant epistemic strategy is the modification of metaphors, which can introduce new research approaches or bridge and moderate across interdisciplinary boundaries (Keller [2003]).

1. **Conclusion**

Researchers in the life sciences often maintain a binary and categorical view of sex despite constantly engaging with variation. We argued that researchers employ the epistemic strategy of IV, which excludes individual variation from the general phenomenon of interest. We identified and exemplified IV using the case of an ornithological field guide, showing how IV stabilises the picture of sex as binary and categorical in this context.

But IV is not the only strategy that researchers can adopt when faced with variation in would-be sex traits. Using the case of the brain sex debate, we have shown that DV is an alternative that works (at least in our case) as a response to IV: it approaches some individual variation that had been treated as mere idiosyncratic variation, and instead treats it as a relevant element of the phenomenon in question. This way, DV was effective in destabilising a dominant binary and categorical picture of brain sex.

We expect that IV and DV are widespread in the life sciences. However, further research could explore further examples of both strategies in other fields or with respect to other scientific concepts or targets of research. This would also help to determine the scope and generalisability of these strategies, as well as to further elaborate their epistemic consequences.[[2]](#footnote-2)

In our second case study, IV and DV exist in a dialectic relationship. One of several interesting implications of this analysis is that IV might sometimes be epistemically detrimental by making a dominant theory persist despite important counter-evidence. In the case of the brain sex debate, DV serves as a way of highlighting counter-evidence, thereby enabling alternative concepts and pictures of sex in this particular research context.

In this regard, a practice-theoretical approach (see section three) to investigating these strategies offers several benefits. For example, we do not know the researchers’ actual intentions in our case studies. Indeed, we assume that researchers do emphatically not want to contribute to practices that mask evidence or stabilise a theory despite counterevidence. Most importantly, thus, we hope that being able to identify IV and DV as epistemic patterns will intentionally be used to improve researchers’ self-reflection by identifying possible unintended effects in their practice, to potentially improve the alignment of their actions and intentions.

Our analysis suggests caution in the employment of IV, especially for sex. An uncritical use of IV may make the binary categorical picture of sex more immune to counter-evidence. This potential immunising function is particularly worrisome in cases where binary and categorical sex concepts interlock with larger socio-cultural systems that reproduce oppression by naturalising a particular picture of sex differences. Fortunately, our analysis highlights a way to counter IV: actively employing DV helps open up the conceptual space where IV had unjustly limited it. This allows drawing on alternative concepts, developing alternative pictures, and fostering more complex and nuanced research questions.

Understanding how IV and DV function can therefore feed into future analyses of how epistemic and non-epistemic aspects of scientific practice, and the social context in which science operates, interact with the effect of maintaining, modifying, or disrupting a given ontological picture that may involve the naturalization of social categories. For example, identifying IV and DV may help investigate how corporate interest in biomedical business or national funding policies like the NIH SABV directive interact with and impact on research practice and how they might be supported or resisted.

**Acknowledgements**

We thank Marina DiMarco, the participants of the ‘Feminist epistemology in Philosophy of Science’ panel at the 4th Lisbon International Conference in Philosophy Of Science (LICPOS) 2023, and two anonymous reviewers at BJPS for very helpful comments on an earlier version of the paper.

**Funding**

This publication is part of the project “The Reconceptualization of Sexual Difference: Exploring Enactivist Approaches and Pluralist Conceptions to Sex-Gender” (with project number 019.221SG.009) of the research programme Rubicon which is financed by the Dutch Research Council (NWO).

This project has received funding from the European Research Council (ERC) under the European Union’s Horizon 2020 research and innovation programme (grant agreement No. 101001145). This paper reflects only the author's view and the Commission / Agency is not responsible for any use that may be made of the information it contains.

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1. This example was selected from the nine free preview pages on Birds of the World (a subscription-only service). It was chosen because it explicitly dealt with the issue of individual variation in relation to sexual dimorphism. [↑](#footnote-ref-1)
2. This research would ideally adopt an empirical approach such as ethnography. Such approaches are particularly well suited to examine processes that underlie scientific concept formation—processes which are often not revealed in scientific publications (Mansnerus and Wagenknecht [2015]; Osbeck and Nersessian [2015]; Nersessian and MacLeod [2022]; Hangel and ChoGlueck [2023]). [↑](#footnote-ref-2)