Sci Eng Ethics (2018) 24:1697–1717
https://doi.org/10.1007/s11948-017-9957-4

ORIGINAL PAPER

Scientists Still Behaving Badly? A Survey Within Industry and Universities

Simon Godecharle[1] · Steffen Fieuws[2] · Ben Nemery[3] · Kris Dierickx[1]

Received: 14 April 2017 / Accepted: 5 August 2017 / Published online: 2 October 2017

Abstract Little is known about research misconduct within industry and how it compares to universities, even though a lot of biomedical research is performed by–or in collaboration with–commercial entities. Therefore, we sent an e-mail invitation to participate in an anonymous computer-based survey to all university researchers having received a biomedical research grant or scholarship from one of the two national academic research funders of Belgium between 2010 and 2014, and to researchers working in large biomedical companies or spin-offs in Belgium. The validated survey included questions about various types of research misconduct committed by respondents themselves and observed among their colleagues in the last three years. Prevalences of misconduct were compared between university and industry respondents using binary logistic regression models, with adjustments for relevant personal characteristics, and with significance being accepted for $p < 0.01$. The survey was sent to 1766 people within universities and an estimated 255 people from industry. Response rates were 43 (767/1766) and 48% (123/255), and usable information was available for 617 and 100 respondents, respectively. In general,

Electronic supplementary material The online version of this article (doi:10.1007/s11948-017-9957-4) contains supplementary material, which is available to authorized users.

✉ Simon Godecharle
simon.godecharle@emmaus.be

Kris Dierickx
kris.dierickx@kuleuven.be

[1] Centre for Biomedical Ethics and Law, Department of Public Health and Primary Care, University of Leuven, Kapucijnenvoer 35, Box 7001, 3000 Louvain, Belgium

[2] Leuven Biostatistics and Statistical Bioinformatics Centre (L-BioStat), Department of Public Health and Primary Care, University of Leuven, 3000 Louvain, Belgium

[3] Centre for Environment and Health, Department of Public Health and Primary Care, University of Leuven, 3000 Louvain, Belgium

research misconduct was less likely to be reported by industry respondents compared to university respondents. Significant differences were apparent for one admitted action (gift authorship) and three observed actions (plagiarism, gift authorship, and circumventing animal-subjects research requirements), always with lower prevalences for industry compared to universities, except for plagiarism. This survey, based on anonymous self-report, shows that research misconduct occurs to a substantial degree among biomedical researchers from both industry and universities.

Keywords Research integrity · Research misconduct · Industry · Universities

Introduction

In 2005, a Nature article revealed that a substantial portion of scientists "behaved badly" and admitted various forms of scientific misbehavior (Martinson et al. 2005). This has been confirmed in numerous other studies of university researchers (Fanelli 2009; Pupovac and Fanelli 2015). Academic researchers often claim that the pharmaceutical industry badly influences biomedical research practice or conducts fraudulent research (Goldacre 2012; Krimsky 2004; DeAngelis and Fontanarosa 2008; Rosenbaum 2015). Industry has indeed been found guilty of various forms of research misconduct (Stossel 2005; Hvistendahl 2013), and it has been shown that "positive" outcomes are more likely for industry funded research than for research funded by other sources (Lexchin et al. 2003). Conversely, researchers from biomedical companies have complained that research published in peer reviewed academic journals is often irreproducible, implicitly accusing academic researchers of unethical practices (Prinz et al. 2011).

Rosenbaum has argued that the academic distrust towards industry is based on emotional rather than rational reasons (Rosenbaum 2015). However, her claim does not rest on much objective evidence, since little or no empirical studies have compared practices and attitudes with regard to research integrity and misconduct between industry and universities. We conducted a large computer-based survey of biomedical researchers and research managers—using a methodology used by others (Martinson et al. 2005)—to test the hypothesis that the experiences and views on research integrity and misconduct differ between those working in industry and those working in universities. By means of this survey, it was determined how often biomedical researchers from universities and industry reported to have committed or observed various forms of research misconduct and the prevalences of reported misbehavior were compared between university-based and industry-based respondents. The relation between the prevalence of observed or admitted research misconduct and several possible predictors, such as age, gender, having obtained a doctoral degree (Ph.D.), level of management, having received mentoring and research integrity training were also investigated.

Methods

We adapted a survey that was used in previous research conducted in the USA (Martinson et al. 2005), on the basis of our review of the research integrity guidance documents in Europe (Godecharle et al. 2013a; Godecharle et al. 2014) and the analysis of 22 semi-structured interviews conducted with biomedical researchers and research managers active in universities or industry in Belgium (Godecharle, Nemery, Dierickx submitted). In our survey, we asked whether the respondents had, in the past three years, committed (themselves) or observed their colleagues committing 22 actions of research misconduct (see Table 1). These responses will be labelled “admitted” and “observed”, respectively, in the further text.

Throughout our article we will not only consider fabrication, falsification and plagiarism to be misconduct, but 22 actions in total, based on our previous research and the USA survey. We grouped these 22 actions of research misconduct into six categories, in line with the previous USA study: ‘data misconduct’, ‘methods misconduct’, ‘credit misconduct’, ‘policy misconduct’, ‘cutting corners misconduct’, and ‘outside influence misconduct’ (Anderson et al. 2007). We also asked respondents to indicate the kinds of mentoring, as well as the kind and the amount of research integrity training, received. Finally, questions were asked about personal characteristics including gender, age, and level of management (without possibilities of identification). A detailed overview of the questions can be found in Table 2.

All instructions and questions were in English (most, if not all, biomedical researchers in Belgium may be expected to have a good working knowledge of English). Opportunities for adding free text were available for several questions. The national Privacy Commission and the “Social and Societal Ethics Committee” of the University of Leuven gave a positive advice for our protocol. We guaranteed anonymity to the individual participants and their organizations. We sent out our online survey from February until May 2015. Up to four reminder e-mails were sent.

Population and Sample

The target population of our survey consisted of biomedical researchers and research managers active within universities or industry in Belgium. We e-mailed a link to our survey to all individuals who had received a grant or scholarship from the two national academic research funders of Belgium (Research Foundation–Flanders; Fonds de la Recherche Scientifique), in 2010, 2011, 2012, 2013 or 2014, for doing biomedical research in a university. Hereby all the 10 Belgian universities were included.

To contact the relevant biomedical companies, we went through several phases. Firstly, we searched and contacted regional and national databases, such as Pharma.be, FlandersBio, Biowin, BrusselsLifetech. In addition, we listed the biomedical spin-offs of all the Belgian universities, and asked the universities whether this list was relevant. Secondly, we contacted each company by phone or e-mail, to verify whether they conducted research (other than marketing or clinical

Table 1 List of 22 actions of research misconduct, grouped per category

Actions of research misconduct	Categories of research misconduct
1. Dropping observations or data points from analyses based on a gut feeling they were inaccurate 2. Willfully distorting research results or data 3. Knowingly overlooking others' use of flawed data or methods 4. Inventing research data or cases 5. Failing to present data that contradict one's own previous research.	(1) Data misconduct
6. Inadequate record keeping or data management related to research projects 7. Using inadequate or inappropriate research designs 8. Withholding key aspects of methodology in papers or proposals	(2) Methods misconduct
9. Circumventing or ignoring aspects of materials-handling requirements (e.g. biosafety, radioactive) 10. Circumventing or ignoring aspects of human-subjects research requirements (e.g. informed consent, …) 11. Circumventing or ignoring aspects of animal-subjects research requirements	(3) Policy misconduct
12. Unauthorized use of confidential information in connection with one's own research 13. Not properly disclosing involvement in firms whose products are based on one's own research 14. Changing the results or conclusions of a study in response to pressure from funding source	(4) Outside influence misconduct
15. Using another's words, data or ideas without giving due credit 16. Denying authorship credit to someone who has contributed substantively to a manuscript 17. Publishing, as original research, ones previously published data or results 18. Giving authorship credit to someone who has not contributed substantively to a manuscript	(5) Credit misconduct
19. Inadequate monitoring of research projects due to work overload 20. Cutting corners in a hurry to complete a project 21. Continued unintentional carelessness in conducting research 22. Inappropriate or careless review of papers or proposals	(6) Cutting corners misconduct

trials) in Belgium. If so, we asked them if they would be willing to let their biomedical researchers and research managers participate in our survey. Of the 50 companies conducting biomedical research in Belgium (from small spin-offs to international corporations), 27 accepted to participate either by giving us the e-mail

Table 2 List of predictors for reported (admitted and observed) research misconduct

	N (%) subjects with available information	Universities	Industry	*p* value
Gender	636 (89)			0.425
Female		46%	41%	
Male		54%	59%	
Age	634 (88)			<0.001
Mean (SD)		38 (11)	44 (10)	
20–29		26%	4%	
30–39		36%	31%	
40–49		20%	39%	
≥50		18%	26%	
Management level	717 (100)			<0.001
Higher management		26%	20%	
Middle management		29%	35%	
Lower management		15%	31%	
Not applicable		30%	14%	
Obtained a degree outside Belgium	636 (89)	23%	43%	<0.001
Obtained a Ph.D.	636 (89)	73%	70%	0.524
Mentorship[a]	717 (100)			
Help in developing professional relationships with others in your field		82%	71%	0.015
Assistance in writing for presentation and publication		93%	87%	0.036
Instruction in the details of good research practice		77%	78%	1.000
Continuing interest in your progress		92%	91%	0.687
Emotional support when needed		67%	56%	0.042
Help in learning the art of survival in your field		65%	56%	0.092
Assistance in obtaining financial support		84%	61%	<0.001
Research integrity training[b]	641 (89)			
More formal research integrity training				
A face-to-face classroom course focused specifically on research integrity		29%	34%	0.386
A section on research integrity within other courses in your field		35%	48%	0.025
Online course focused specifically on research integrity		14%	42%	<0.001
More informal research integrity training				
Workshops, conferences, roundtable discussions, etc.		45%	37%	0.138

Table 2 continued

	N (%) subjects with available information	Universities	Industry	*p* value
Discussions with instructors, mentors, or colleagues		82%	81%	0.883

A comparison is made between respondents from universities and industry. *p* values are from Fisher's exact tests or Mann–Whitney-*U* tests

[a] Some/a lot versus none

[b] A great deal/some versus none

addresses of their eligible employees (11 companies) or by sending an invitation to participate in the survey to their eligible employees (16 companies).

Validity

To calculate the content validity index, we consulted three experts: the chairman of the Flemish Commission for Scientific Integrity; the director of a doctoral school of one of the Belgian French speaking universities; the person responsible for research ethics at a major international biomedical company active in Belgium. They ranked all the individual questions on a 4-point Likert scale, ranging from 'not relevant' to 'highly relevant'. We revised or removed questions that all three experts did not consider relevant. Afterwards, the revised questions were reviewed again by all three experts. Our survey had a content validity index (S-CVI/Ave) of 0.98 (Polit et al. 2007).

We also conducted a pilot study by sending the survey to the 15 Steering Committee members (active in industry or universities) of the Belgian Society of Toxicology and Ecotoxicology. We obtained a response rate of 53% for this pilot. The survey scored well on face-validity and user-friendliness.

Statistical Analyses

Fisher's exact tests and Mann–Whitney-U tests were used to compare variables between respondents active in universities and industry. Associations between admitted and observed behavior were evaluated with Spearman correlations. Binary logistic regression models were used to evaluate possible determinants for reporting research misconduct. Analyses were performed for each action separately, for all actions ('presence' being defined as replying 'yes' for at least one of the 22 actions), and per category of misconduct ('presence' being defined as replying 'yes' to at least one of the actions belonging to the specific category). To handle missing information in the considered predictors, a multivariate imputation was performed using the fully conditional specification (FCS) approach (Van Buuren 2007). In this approach, for each of the variables with a missing value, a regression model was specified using all other predictors and all outcome variables as covariates. Depending on the variable, a linear regression, binary logistic or ordinal logistic regression model was used. The process was iterated (one iteration consists of one cycle through all variables) until convergence to the multivariate distribution was obtained. Ten complete datasets were created and a multivariable logistic regression model was fitted in each of the datasets. The results of the ten analyses performed on the ten completed datasets were combined using Rubin's rule (Rubin 1987). Two versions of the multivariable model were considered. First, the difference between university and industry was evaluated after correction for age, gender, holding a Ph.D., having obtained a degree abroad, and level of management (model A). Second, having received mentoring and research integrity training were added (model B). The predictors considered in the latter model were determined based on a backward stepwise selection procedure with 0.157 as the critical level for the p value. The model reduction was performed on a stacked dataset consisting of the multiple imputed data, using a weighting scheme to account for the fraction of missing data in each covariate (Wood et al. 2008). The odds ratios (with 95% confidence intervals) reported in the text, refer to the result of multivariable model B. Given the multitude of performed tests, only p values smaller than 0.01 (instead of the classical 0.05) were considered significant. All analyses have been performed using SAS software, version 9.4 of the SAS System for Windows.

Results

As summarized in Fig. 1, the survey was sent by e-mail to 1766 people within universities, and to an estimated 255 people from industry. Although the exact denominator was unknown for participants from industry, we estimated the survey was delivered to 255 people, based on fragmentary information received from the

Respondents			
	Total	Universities	Industry
	↓	↓	↓
Target population	2021	1766	255*
	↓	↓	↓
Respondents	890	767	123
	↓ No or incomplete information: N=173	↓	↓
Final sample	717	617	100

* Estimation

Fig. 1 Flowchart providing an overview of respondents to our survey companies about the numbers of e-mails sent out to their employees. A total of 890 persons responded to the survey (767 working in universities and 123 working in industry) thus yielding response rates of 43% (767/1766) and 48% (123/255), respectively. For some respondents, no information (N = 165) or only incomplete information (N = 8) was available on reported behavior (observed combined with admitted), leaving a final analysis sample of 717 subjects (617 in universities and 100 in industry).

Respondents from universities and industry did not differ strongly in terms of gender or being holder of a Ph.D. (Table 2). Respondents from industry were almost twice as likely to have obtained a degree outside Belgium than those in universities. Because university respondents included nearly seven times more young people (age 20–29) than industry, the proportions of senior versus junior management level differed between the two groups.

Overall, respondents from universities had received more mentoring from their promoters, supervisors, etc. This difference was significant for having received assistance in obtaining financial support. Additionally, more respondents from industry indicated they had followed research integrity training compared to universities, with a significant difference for online research integrity training.

The prevalence of reporting both admitted and observed research misconduct was generally higher within universities than within industry: 71% of respondents from universities compared to 61% of respondents from industry admitted at least one of the 22 actions. Similarly, 93% of the respondents from universities and 84% of those from industry reportedly observed at least one of the 22 actions being done by their colleagues. However, this latter difference did not reach significance in multivariable model B (see Tables 3 and 4).

We observed a positive relation between having observed and admitting research misconduct. Participants who observed more actions also admitted to more actions themselves, among respondents from either universities ($\rho = 0.63$, $p < 0.001$) or industry ($\rho = 0.65$, $p < 0.001$).

Significant differences were apparent for three observed misconduct actions (plagiarism, gift authorship, and circumventing animal-subjects research requirements) and one admitted misconduct action (gift authorship), with lower prevalences being found for industry compared to universities, except for plagiarism (see Tables 3 and 4). Gift authorship was reported frequently in both contexts: it was observed by 50% of respondents from industry and by 76% of respondents from universities; it was admitted within industry by 25% of the respondents, compared to 42% within universities, thus making gift authorship about half less likely to occur within industry compared to universities. In contrast, plagiarism was twice more likely observed and three times more likely admitted by respondents from industry compared to those from universities.

Fewer than half of the respondents (47% in industry and 22% in universities; $p < 0.001$; not shown in Tables) were confident that fraud would always be detected in their organization. Within industry 79, against 52% within universities, were willing to report a case of research misconduct ($p < 0.001$; not shown in Tables). Many academics did not know whether they would report a case (38%) or stated they would not do it (10%). The main reasons why one would not report a case,

Table 3 Industry–university comparison of reporting rate of observed research misconduct

	Total (n = 717) (%)	Industry (n = 100) (%)	Academia (n = 617) (%)	Univariable		Multi A		Multi B	
				OR (95% CI)	*p*	OR (95% CI)	*p*	OR (95% CI)	*p*
Data misconduct									
Dropping data based on a gut feeling	40	36	41	0.81 (0.52;1.25)	0.345	0.90 (0.56;1.45)	0.661		
Falsification (wilfully distorting research results or data)	12	9	12	0.70 (0.34;1.46)	0.344	0.68 (0.31;1.47)	0.329	0.54 (0.25;1.16)	0.117
Overlooking others' use of flawed data or methods	17	10	19	0.49 (0.24;0.96)	0.038	0.53 (0.26;1.09)	0.083	0.51 (0.25;1.02)	0.058
Fabrication (inventing research data or cases)	4	3	4	0.73 (0.22;2.47)	0.616	0.67 (0.18;2.42)	0.539		
Not presenting data that contradicting previous research	21	20	21	0.92 (0.54;1.55)	0.752	0.99 (0.57;1.75)	0.985		
Methods misconduct									
Inadequate record keeping or data management	48	41	49	0.72 (0.47;1.11)	0.141	0.78 (0.49;1.24)	0.292		
Using inadequate or inappropriate research designs	45	39	46	0.74 (0.48;1.14)	0.172	0.78 (0.49;1.23)	0.283	0.72 (0.46;1.12)	0.1460
Withholding key aspects of methodology	17	12	18	0.61 (0.33;1.16)	0.135	0.67 (0.34;1.32)	0.247		
Policy misconduct									
Circumventing materials-handling requirements	32	21	34	0.52 (0.31;0.87)	0.013	0.57 (0.33;0.98)	0.043	0.57 (0.33;0.97)	0.039
Circumventing human-subjects research requirements	17	9	18	0.44 (0.21;0.89)	0.023	0.44 (0.20;0.93)	0.032	0.40 (0.19;0.85)	0.016
Circumventing animal-subjects research requirements.	13	5	15	0.31 (0.12;0.78)	0.013	0.29 (0.11;0.76)	0.012	0.29 (0.11;0.74)	0.009

Table 3 continued

	Total (n = 717) (%)	Industry (n = 100) (%)	Academia (n = 617) (%)	Univariable		Multi A		Multi B	
				OR (95% CI)	*p*	OR (95% CI)	*p*	OR (95% CI)	*p*
Outside influence misconduct									
Unauthorized use of confidential information	9	5	9	0.51 (0.20;1.30)	0.157	0.49 (0.18;1.30)	0.152	0.43 (0.16;1.14)	0.090
Not properly disclosing involvement in firms	5	3	5	0.55 (0.16;1.82)	0.325	0.69 (0.19;2.44)	0.560		–
Changing the results in response to pressure from funder	4	4	4	1.13 (0.38;3.34)	0.829	1.10 (0.34;3.49)	0.875		–
Credit misconduct									
Plagiarism (coping words/data/ideas without credit)	36	51	34	2.02 (1.32;3.09)	0.001	1.97 (1.24;3.11)	0.004	2.10 (1.36;3.24)	<0.001
Denying authorship credit	33	29	34	0.80 (0.50;1.27)	0.338	0.83 (0.51;1.36)	0.465		–
Publishing again one's previously published data	9	6	10	0.60 (0.25;1.44)	0.254	0.60 (0.24;1.51)	0.279		–
Gift authorship	72	50	76	0.32 (0.21;0.50)	<.0001	0.42 (0.26;0.68)	<0.001	0.41 (0.26;0.67)	<0.001
Cutting corners misconduct									
Inadequate monitoring of research projects	65	54	67	0.59 (0.38;0.90)	0.015	0.74 (0.46;1.18)	0.210	0.65 (0.42;1.01)	0.056
Cutting corners in a hurry to complete a project	33	34	33	1.04 (0.67;1.63)	0.853	1.03 (0.64;1.66)	0.909		–
Continued carelessness in conducting research	25	16	27	0.53 (0.30;0.92)	0.025	0.55 (0.31;1.00)	0.048	0.53 (0.30;0.95)	0.032
Inappropriate or careless review of papers or proposals	27	18	28	0.56 (0.33;0.97)	0.037	0.56 (0.32;1.00)	0.050	0.55 (0.32;0.96)	0.035

Table 3 continued

	Total (n = 717) (%)	Industry (n = 100) (%)	Academia (n = 617) (%)	Univariable		Multi A		Multi B	
				OR (95% CI)	*p*	OR (95% CI)	*p*	OR (95% CI)	*p*
Total									
Observed at least one of the 22 listed actions	91	84	93	0.42 (0.23;0.78)	0.006	0.58 (0.28;1.19)	0.138	0.35 (0.18;0.68)	0.002

The actions listed are abbreviated forms of the full questions asked, which can be found in Table 1. Odds ratios (industry versus university) for the difference in reported behavior between industry and academia. Model A = result from the multivariable model with correction for factors age, gender, obtained a Ph.D., obtained a degree abroad, and level of management. Model B = result from multivariable model considering all variables and applying a backward stepwise model selection. In the multivariable model B no odds ratio is reported for the effect of context if context was not retained as factor in the multivariable model. No univariable odds ratios were given if in academia and/or industry the behavior is not observed/reported. No multivariable models were fitted if the total number of events was lower than 10

Table 4 Industry–university comparison of reporting rate of admitted research misconduct

	Total (n = 717) (%)	Industry (n = 100) (%)	Academia (n = 617) (%)	Univariable		Model A		Model B	
				OR (95% CI)	*p*	OR (95% CI)	*p*	OR (95% CI)	*p*
Data misconduct									
Dropping data based on a gut feeling	15	15	15	1.02 (0.56; 1.84)	0.947	1.26 (0.66; 2.42)	0.484		–
Falsification (wilfully distorting research results or data)	0	0	0		–		–		–
Overlooking others' use of flawed data or methods	6	4	6	0.67 (0.23; 1.93)	0.461	0.68 (0.22; 2.11)	0.506		–
Fabrication (inventing research data or cases)	0	1	0		–		–		–
Not presenting data contradicting previous research.	4	2	4	0.45 (0.10; 1.91)	0.276	0.49 (0.11; 2.23)	0.357	0.32 (0.07; 1.40)	0.131
Methods misconduct									
Inadequate record keeping or data management	27	22	27	0.75 (0.45; 1.24)	0.259	0.80 (0.47; 1.36)	0.406		–
Using inadequate/inappropriate research designs	15	17	15	1.17 (0.66; 2.06)	0.590	1.17 (0.63; 2.19)	0.615		–
Withholding key aspects of methodology	5	3	5	0.57 (0.17; 1.88)	0.353	0.61 (0.18; 2.15)	0.446		–
Policy misconduct									
Circumventing materials-handling requirements	11	4	13	0.29 (0.10; 0.80)	0.018	0.31 (0.11; 0.91)	0.033	0.28 (0.10; 0.79)	0.016
Circumventing human-subjects research requirements	5	2	5	0.39 (0.09; 1.64)	0.197	0.34 (0.07; 1.60)	0.171		–
Circumventing animal-subjects research requirements.	3	1	3	0.32 (0.04; 2.40)	0.267	0.30 (0.03; 2.53)	0.267		–

Table 4 continued

	Total (n = 717) (%)	Industry (n = 100) (%)	Academia (n = 617) (%)	Univariable		Model A		Model B	
				OR (95% CI)	*p*	OR (95% CI)	*p*	OR (95% CI)	*p*
Outside influence misconduct									
Unauthorized use of confidential information	1	2	1	1.78 (0.36; 8.69)	0.477		–		–
Not properly disclosing involvement in firms	1	1	1	1.55 (0.17; 13.99)	0.697		–		–
Changing results in response to pressure from funder	0	1	0	3.11 (0.28; 34.58)	0.357		–		–
Credit misconduct									
Plagiarism (coping words/data,/ideas without credit)	4	7	3	2.37 (0.97; 5.79)	0.058	2.62 (1.00; 6.83)	0.049	2.86 (1.13; 7.26)	0.027
Denying authorship credit	2	1	2	0.51 (0.07; 3.96)	0.519	0.52 (0.06; 4.25)	0.538		–
Publishing again one's previously published data	0	1	0	3.11 (0.28; 34.58)	0.357		–		–
Gift authorship	40	25	42	0.46 (0.28; 0.74)	0.001	0.50 (0.30; 0.84)	0.008	0.52 (0.32; 0.85)	0.009
Cutting corners misconduct									
Inadequate monitoring of research projects	36	37	36	1.04 (0.67; 1.61)	0.868	1.13 (0.70; 1.83)	0.617		–
Cutting corners in a hurry to complete a project	13	18	12	1.64 (0.93; 2.88)	0.088	1.44 (0.77; 2.67)	0.252	1.98 (1.10; 3.55)	0.022
Continued carelessness in conducting research	2	2	2	1.12 (0.25; 5.15)	0.880	1.26 (0.24; 6.51)	0.783		–
Inappropriate review of papers or proposals	4	4	4	1.08 (0.36; 3.18)	0.895	0.61 (0.18; 2.08)	0.431		–

Table 4 continued

	Total (n = 717) (%)	Industry (n = 100) (%)	Academia (n = 617) (%)	Univariable		Model A		Model B	
				OR (95% CI)	*p*	OR (95% CI)	*p*	OR (95% CI)	*p*
Total									
Admitted at least one of the 22 listed actions	70	61	71	0.63 (0.48; 0.97)	0.035	0.69 (0.42; 1.12)	0.138	0.70 (0.44; 1.10)	0.124

The actions listed are abbreviated forms of the full questions asked, which can be found in Table 1. Odds ratios (industry versus university) for the difference in reported behavior between industry and academia. Model A = result from the multivariable model with correction for factors age, gender, obtained a Ph.D., obtained a degree abroad, and level of management. Model B = result from multivariable model considering all variables and applying a backward stepwise model selection. In the multivariable model B no odds ratio is reported for the effect of context if context was not retained as factor in the multivariable model. No univariable odds ratios were given if in academia and/or industry the behavior is not observed/reported. No multivariable models were fitted if the total number of events was lower than 10 were the lack of protection of whistleblowers for participants in industry and the possible harm of relationships with colleagues for universities.

When the separate actions were grouped in six categories, as done by the previous USA research (Anderson et al. 2007), then 'policy misconduct', either observed or committed, stands out as being less likely to be reported by industry than academia. The other categories were also less frequently reported by industry respondents, however without reaching our stringent level of significance ($p < 0.01$) (see Table 5).

Tables 6 and 7 (electronic supplement) provide an overview of the relations between possible predictors and the reporting of research misconduct for each of the six categories taken separately. A positive relation was present between level of management and observing forms of 'outside influence misconduct'. Respondents with a higher and middle management position observed more 'method misconduct' being done by their colleagues. Respondents holding a Ph.D. observed and admitted to more forms of 'credit misconduct', than respondents without a Ph.D. Respondents who had completed a degree outside Belgium admitted fewer forms of 'cutting corner misconduct'. There were no significant relations with age.

Respondents who reported having received an informal kind of research integrity training, generally observed and admitted more forms of misconduct. For example, respondents who indicated they had received research integrity training by "workshops, conferences, roundtable discussions" observed ($p = 0.013$) and admitted ($p = 0.007$) to more 'outside influence misconduct'. In contrast, formal research integrity training resulted in a lower reporting of various forms of research misconduct. Respondents who indicated they had received research integrity training by "a section on research integrity within other courses in your field" admitted to significantly fewer forms of 'cutting corner misconduct' ($p = 0.001$). Equally, receiving various forms of mentoring generally related with reporting fewer forms of research misconduct. Respondents who had received "instruction in the details of good research practice" observed significantly fewer forms of data misconduct ($p = 0.002$),

In our survey we did not ask about the nationality of the respondents, due to privacy reasons. Nevertheless, at least 19% of survey participants indicated having obtained a degree outside Belgium (165/890 respondents, 254 not answering the question), with 156 specifying in which country: 118 had obtained a degree inside the European Economic Area, with France (n = 21), The Netherlands (n = 21), Germany (n = 20), Italy (n = 16), and United Kingdom (n = 15) as the most mentioned countries. Various other regions were also represented: North America (9 in the United States, 5 in Canada), Asia (3 in China, 3 in India, 1 in South Korea), Africa (2 in South Africa, 1 in Morocco, 1 in Kenya, 1 in Zimbabwe), the Middle East (3 in Iran, 1 in Israel), South America (1 in Venezuela, 1 in Cuba, 1 in Brazil), 2 in Russia and 2 in Australia. 1 respondent indicated an unknown or invalid region.

Table 5 Industry–university comparison of reporting rate of research misconduct per category

	Total (n = 717) (%)	Industry (n = 100) (%)	Academia (n = 617) (%)	Univariable		Multi A		Multi B	
				OR (95% CI)	*p*	OR (95% CI)	*p*	OR (95% CI)	*p*
Reportedly observed behavior									
Data misconduct	55	47	56	0.69 (0.45; 1.05)	0.086	0.765 (0.48; 1.22)	0.264	0.661 (0.43; 1.02)	0.060
Methods misconduct	66	60	67	0.75 (0.49; 1.16)	0.197	0.795 (0.49; 1.30)	0.358		–
Policy misconduct	45	29	48	0.45 (0.28; 0.71)	<0.001	0.428 (0.26; 0.71)	0.001	0.393 (0.24; 0.64)	<0.001
Outside influence misconduct	16	11	16	0.63 (0.33; 1.22)	0.173	0.621 (0.30; 1.27)	0.191	0.600 (0.30; 1.19)	0.146
Credit misconduct	81	70	83	0.49 (0.30; 0.79)	0.003	0.695 (0.40; 1.20)	0.195	0.535 (0.33; 0.87)	0.012
Cutting corners misconduct	75	66	76	0.60 (0.38; 0.94)	0.025	0.697 (0.42; 1.16)	0.165	0.641 (0.40; 1.02)	0.062
Reportedly admitted behavior									
Data misconduct	21	21	21	0.99 (0.59; 1.66)	0.958	1.449 (0.95; 2.21)	0.085		–
Methods misconduct	36	34	36	0.90 (0.58; 1.41)	0.656	0.916 (0.56; 1.49)	0.722		–
Policy misconduct	17	6	19	0.28 (0.12; 0.64)	0.003	0.267 (0.11; 0.66)	0.004	0.278 (0.12; 0.66)	0.004
Outside inflence misconduct	2	4	2	1.94 (0.62; 6.06)	0.257	1.364 (0.39; 4.83)	0.631		–
Credit misconduct	41	31	43	0.59 (0.38; 0.93)	0.024	0.615 (0.38; 1.01)	0.053	0.669 (0.42; 1.07)	0.092

Table 5 continued

	Total (n = 717) (%)	Industry (n = 100) (%)	Academia (n = 617) (%)	Univariable		Multi A		Multi B	
				OR (95% CI)	*p*	OR (95% CI)	*p*	OR (95% CI)	*p*
Cutting corners misconduct	43	43	43	1.02 (0.66; 1.56)	0.944	1.070 (0.67; 1.72)	0.781		–

Odds ratios (industry versus university) for the difference in reported behavior between industry and academia. Model A = result from the multivariable model with correction for factors age, gender, obtained a Ph.D., obtained a degree abroad, and level of management. Model B = result from multivariable model considering all variables and applying a backward stepwise model selection. In the multivariable model B no odds ratio is reported for the effect of context if context was not retained as factor in the multivariable model. No univariable odds ratios were given if in academia and/or industry the behavior is not observed/reported. No multivariable models were fitted if the total number of events was lower than 10

Discussion

Within the limits of our cross-sectional survey of self-reported personal and observed misbehavior, we may conclude that, in spite of reassuring claims (Rosenbaum 2015), research misconduct occurs to a substantial degree within both universities and industry. Overall, the reporting of research misconduct was lower in industry compared to universities, expect for plagiarism.

A novelty and strength of our survey compared to previous studies (Martinson et al. 2005; Fanelli 2009), is that we also included researchers working in industry. Nevertheless our study also has limitations. First, privacy issues initially complicated obtaining the e-mail addresses of potential participants, especially from industry. Some companies were initially suspicious and reluctant to participate, despite our pledges of full anonymity, and certain big corporations eventually declined after months of intense communication. Several companies wanted to read the article before its publication. Second, our survey does not allow us to explain why we found a possibly lower prevalence of research misconduct in industry than in universities. We cannot exclude a selection bias (with the "most ethical" fraction of the industrial population having been invited or having consented to participate in the survey) or a reporting bias (with respondents from industry having been more inclined to give socially acceptable replies). However, the prevalence of self-reported admitted and observed research misconduct may well be truly lower in industry than in universities. Nevertheless, it has been suggested that the case that research performed by industry is technically clean, does not necessarily guarantee that its conclusions are unbiased, let alone ethical (Smith 2005). Third, one could question the generalizability of a study that was done in a single, small country. However, our participants had various international backgrounds and they worked in a wide range of organizations, including multinational pharmaceutical companies. There are no reasons to assume that the Belgian research situation differs from that of other industrialized Western countries. Finally, one could object that we performed a large number of comparisons and verified many relations. This is why we interpreted single significant p values with caution and adopted a stringent criterion ($p < 0.01$) to accept statistical significance.

Fourth, we relied on the (self-) reporting of our respondents, which does not provide a solid base to verify the exact amount of research misconduct that was conducted. In addition, the prevalence of observed research misconduct is challenging to interpret. It is possible that certain respondents refer to the same case of research misconduct. It is also possible that respondents interpreted the actions of research misconduct we inquired about, in a different way than we had intended. Nevertheless, we used descriptive phrases instead of terms in order to describe the action of research misconduct. Finally, one could criticize the two different modalities to recruit participants: all Belgian universities were included, whereas not all private companies, including several multinational corporations, accepted to participate. We do not know to what extent this selective participation by organization introduced a systematic bias. Neither do we know how this may have introduced bias at the level of individual respondents. Unfortunately we have no way of asserting the level of bias. However, our study is the first study that also included researchers working in industry.

The prevalences of admitted and observed misconduct actions in our survey proved to be generally of similar magnitude as those found in other surveys on research integrity (Martinson et al. 2005; Fanelli 2009; Titus et al. 2008; Tavare 2012). However, the prevalence of 'credit misconduct' stands out as being much higher in our survey than in the previous USA survey (Martinson et al. 2005). This is partly explained by differences in the way the category of 'credit misconduct' was built. In the USA survey, plagiarism (one of the components of 'credit misconduct') was admitted to by 1% of the respondents, compared to 3% in our survey (Martinson et al. 2005). In addition, in the USA survey, 10% admitted to "inappropriately assigning authorship credit", whereas in our survey, where two questions referred to this issue, 2% admitted to "denying authorship credit to someone who has contributed substantively", but up to 42% to "giving authorship credit to someone who has not contributed substantively" (Martinson et al. 2005).

According to Stroebe et al. most research misconduct cases are brought to light by whistleblowers (Stroebe et al. 2012). Therefore, it is remarkable that respondents from universities appear more reluctant than those active within industry to report research misconduct. Consequently, many instances of research misconduct might remain unnoticed and, therefore, unsanctioned. Such impunity may favor a culture where research misconduct and questionable research practices become tolerated or even considered 'normal' research practice.

Previous research has questioned the effectiveness of research integrity training to reduce research misconduct and strongly underlined the impact of mentorship on the prevalence of research misconduct (Anderson et al. 2007; Kornfeld 2012). We also found a relation between mentoring and the reporting rate of research misconduct, as well as a (strong) relation between research integrity training and reporting research misconduct. Receiving informal research integrity training, resulted in a higher reporting rate of research misconduct. In contrast, respondents having received formal research integrity training, namely a section on research integrity within other courses, were less likely to observe and admit to research misconduct. Of note, respondents from universities reported having received less formal research integrity training compared to industry.

A recent meta-analysis has shown evolutions in the least years concerning research integrity training. It concludes that such trainings in general are improving. However, the authors emphasize that there is still room for improvement. Several elements have an effect on the impact of research integrity training, including the characteristics of the trainers as well as the trainees, the format, the scope, and the frequency by which the trainings are given (Logan L. Watts et al. 2016). It is noteworthy that concerning these vital elements, there is no consensus in the European guidance documents on research integrity (Godecharle et al. 2013b).

In spite of the ever increasing collaboration between industry and universities, contextual differences between these various environments have been largely ignored in research integrity guidance documents (Godecharle et al. 2013a, 2014). Guidelines that are not based on empirical data, but on assumptions and mutual distrust, might unnecessarily hinder industry–university collaborations (Rosenbaum 2015).

Various questions raised by our research remain unanswered. How can the observed difference in reporting between industry and universities be explained? Why is there such a difference in the reporting of credit misconduct within our survey compared to previous surveys? Does research integrity training effectively stimulate research integrity in the daily research practice or does it rather correlate with providing more socially desirable answers to our survey? Nonetheless, our research demonstrates that, despite the increased attention given to (un)acceptable research practices, a substantial part of biomedical researchers and research managers still engage in research misconduct.

Acknowledgements This research was funded by Research Foundation—Flanders (Fonds Wetenschappelijk Onderzoek–Vlaanderen) Ph.D. Fellowship: 11U8214 N. We thank Dr. de Vries one of the authors of the original USA survey[11] for helping in the process of updating and processing.

Funding This research was funded by Research Foundation—Flanders (Fonds Wetenschappelijk Onderzoek–Vlaanderen), Ph.D. Fellowship: 11U8214 N.

Author Contribution BN and KD contributed to the study design, the elaboration of the manuscript, and supervised the research. Statistical analyses were performed by SF. SG contacted the organizations involved, performed the validation of the survey and the pilot study, performed the study and wrote the first and successive drafts of the manuscript. All authors approved the final version.

Compliance with Ethical Standards

Conflict of interest The authors declare that they have no conflict of interest.

References

Anderson, M. S., Horn, A. S., Risbey, K. R., Ronning, E. A., De Vries, R., & Martinson, B. C. (2007). What do mentoring and training in the responsible conduct of research have to do with scientists' misbehavior? Findings from a National Survey of NIH-funded scientists. *Academic Medicine, 82,* 853–860.

Biowin: http://www.biowin.org/biowin/fr/5408-accueil.html.

BrusselsLifetech: http://lifetechbrussels.com/.

DeAngelis, C. D., & Fontanarosa, P. B. (2008). Impugning the integrity of medical science: The adverse effects of industry influence. *JAMA, 299,* 1833–1835.

Fanelli, D. (2009). How many scientists fabricate and falsify research? A systematic review and meta-analysis of survey data. *PLoS ONE, 4,* e5738.

FlandersBio: http://flandersbio.be/.

Fonds de la Recherche Scientifique (FNRS): http://www.frs-fnrs.be/.

Godecharle, S., Nemery, B., & Dierickx, K. (2013a). Guidance on research integrity: No union in Europe. *Lancet, 381,* 1097–1098.

Godecharle, S., Nemery, B., & Dierickx, K. (2013b). Integrity training: Conflicting practices. *Science, 340,* 1403.

Godecharle, S., Nemery, B., & Dierickx, K. (2014). Heterogeneity in European research integrity guidance: Relying on values or norms? *JERHRE, 9,* 1–12.

Goldacre, B. (2012). *Bad pharma: how drug companies mislead doctors and harm patients*. London: Harper Collins UK.
Hvistendahl, M. (2013). Corruption and research fraud send big chill through big pharma in China. *Science, 341,* 445–446.
Kornfeld, D. (2012). Perspective: Research misconduct: The search for a remedy. *Academic Medicine, 87,* 877–882.
Krimsky, S. (2004). *Science in the private interest. has the lure of profits corrupted biomedical research?*. Lanham: Rowman & Littlefield Publishers.
Lexchin, J., Bero, L. A., Djulbegovic, B., & Clark, O. (2003). Pharmaceutical industry sponsorship and research outcome and quality: Systematic review. *BMJ, 326,* 1167–1170.
Martinson, B. C., Anderson, M. S., & De Vries, R. (2005). Scientists behaving badly. *Nature, 435,* 737–738.
Pharma.be: http://pharma.be/nl/.
Polit, D. F., Beck, C. T., & Owen, S. V. (2007). Is the CVI an acceptable indicator of content validity? Appraisal and recommendations. *Research in Nursing & Health, 30,* 459–467.
Prinz, F., Schlange, T., & Asadullah, K. (2011). Believe it or not: how much can we rely on published data on potential drug targets? *Nature reviews Drug discovery, 10,* 712.
Pupovac, V., & Fanelli, D. (2015). Scientists admitting to plagiarism: A meta-analysis of surveys. *Science and Engineering Ethics, 21*(5), 1331–1352.
Research Foundation—Flanders (FWO): http://www.fwo.be/en/.
Rosenbaum, L. (2015a). Conflicts of Interest: Reconnecting the Dots—Reinterpreting Industry-Physician Relations. *New England Journal of Medicine, 372,* 1860–1864.
Rosenbaum, L. (2015b). Conflicts of interest: beyond moral outrage—Weighing the trade-offs of COI regulation. *New England Journal of Medicine, 372,* 2064–2068.
Rubin, D. B. (1987). *Multiple imputation for nonresponse in surveys*. New York: John Wiley and Sons.
Smith, R. (2005). Medical journals are an extension of the marketing arm of pharmaceutical companies. *PLoS Medicine, 2,* e138.
Stossel, T. P. (2005). Regulating academic—Industrial research relationships—Solving problems or stifling progress. *New England Journal of Medicine, 353,* 1060–1065.
Stroebe, W., Postmes, T., & Spears, R. (2012). Scientific misconduct and the myth of self-correction in science. *Perspectives on Psychological Science, 7,* 670–688.
Tavare, A. (2012). Scientific misconduct is worryingly prevalent in the UK, shows BMJ survey. *BMJ, 344,* e377. doi:10.1136/bmj.e377.
Titus, S. L., Wells, J. A., & Rhoades, L. J. (2008). Repairing research integrity. *Nature, 453,* 980–982.
Van Buuren, S. (2007). multiple imputation of discrete and continuous data by fully conditional specification. *Statistical Methods in Medical Research, 16,* 219–242.
Watts, L. L., et al. (2016). Are ethics training programs improving? A meta-analytic review of past and present ethics instruction in the sciences. *Ethics & Behavior, 27,* 351–384. doi:10.1080/10508422.2016.1182025.
Wood, A. M., White, I. R., & Royston, P. (2008). How should variable selection be performed with multiply imputed data? *Statistics in Medicine, 27,* 3227–3246.