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Developing a strategy to improve data sharing in health research: A mixed-methods study to identify barriers and facilitators

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4 1 **Developing a strategy to improve data sharing in health research: A mixed-**
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6 2 **methods study to identify barriers and facilitators**
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48 20 **Short title:** Data sharing behaviour in health research
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3 **21 Abstract**
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5 **22 Background:** It is well accepted that data sharing presents new opportunities across
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8 **23** the spectrum of research and is vital towards science that is open; where data are
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10 **24** easily discoverable, accessible, intelligible, reproducible, replicable, and verifiable.
11
12 **25** Despite this, it is yet to become common practice. Global efforts to develop practical
13
14 **26** guidance for data sharing and open access initiatives are underway, however
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16
17 **27** evidence-based studies to inform the development and implementation of effective
18
19 **28** strategies are lacking.

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21
22 **29 Objective:** This study sought to determine the barriers and facilitators to data sharing
23
24 **30** among health researchers and to identify the target behaviours for designing a
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27 **31** behaviour change intervention strategy.

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30 **32 Method:** Data are drawn from a cross-sectional survey of data management
31
32 **33** practices among health researchers from one Australian research institute.
33
34 **34** Determinants of behaviour are theoretically derived using well established
35
36
37 **35** behavioural models.

38
39
40 **36 Results:** The data sharing practices are described for 77 researchers. Six barriers
41
42 **37** and four facilitators are identified. The primary barriers to data sharing include:
43
44 **38** perceived negative consequences, and lack of competency to share data. The
45
46
47 **39** primary facilitators to data sharing include: trust in others using the data, and social
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49 **40** influence related to public benefit. Intervention functions likely to be most effective at
50
51 **41** changing target behaviours are also identified.

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54 **42 Conclusion:** Results of this study provide a theoretical and evidence-based process
55
56 **43** to understand the behavioural barriers and facilitators of data sharing among health
57
58
59 **44** researchers.
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3 45 Implications: Designing interventions that specifically address target behaviours to
4
5 46 promote data sharing is important for open researcher practices.
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10 48 **Keywords (Mesh):** data sharing, health information management, research
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15 50 **Supplementary keywords:** behaviour change, COM-B model, intervention design
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20 52 **Article type:** Research
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53 Introduction

54 While data sharing and reuse is more common in some academic disciplines than
55 others, the argument for and against is remarkably similar. Researchers may be
56 motivated to share data if it results in greater visibility or increased citation of their
57 work, if a supportive data sharing culture exists in their workplace, or if they have
58 had positive experiences with open data reuse (Patel, 2016; Piwowar, 2011;
59 Piwowar et al., 2007; Zuiderwijk and Spiers, 2019). Conversely, researchers are
60 demotivated to share data if they are concerned about privacy, fear of reputation or
61 “scooping” of research, have a desire to retain exclusive rights to data, or are
62 concerned about the inflation, misinterpretation or the usability of data (Alter and
63 Vardigan, 2015; Arzberger et al., 2004; Campbell and Bendavid, 2003; Cheah et al.,
64 2015; Kuipers and van der Hoeven J., 2009; Savage and Vickers, 2009; Tenopir et
65 al., 2011; Zuiderwijk and Spiers, 2019). The perceptions and practices of data
66 sharing and data reuse among researchers was examined by Tenopir et al. (2015),
67 who observed significant increases in the willingness and acceptance of sharing, and
68 “actual” data sharing over a 4-year period. This was also met with an increase in the
69 perception of risk associated with data sharing, including the potential for misuse and
70 misinterpretation and concern about the need to publish data before making it
71 became available. The study also describes that receiving acknowledgement, or a
72 formal citation was important when deciding whether to share data. The Wiley Data
73 Insights survey of more than 4500 researchers from 112 countries indicates a range
74 of motivations for data sharing, including: to increase impact and visibility of
75 research, public benefit, transparency and reuse, or journal requirement (Ferguson,
76 2014). Australian researchers were most incentivised to share data to ensure
77 preservation, transparency and reuse, or to satisfy a funding requirement. This

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3 78 survey demonstrates that support for open researcher practices may not directly
4
5 79 translate into data sharing practices; rather influenced by the increased scientific
6
7 80 competitiveness of research, the research environment specific to the country, or the
8
9 81 appeal for commercial application.
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13 82 In Australia, around 75% of universities have an open access mandate, policy or
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15 83 statement, including the two major funding agencies: the National Health and
16
17 84 Medical Council and the Australian Research Council (Australian Research Council,
18
19 85 2017; National Health and Medical Research Council, 2018). Despite this support,
20
21 86 the one shortcoming and arguably the most important feature of open practices, is
22
23 87 the lack of participation in data sharing from the research community (Ali-Khan et al.,
24
25 88 2017; Hauessler, 2011). Tenopir and colleagues (2011) report that < 6% of
26
27 89 international researchers make “all” their data available, and while only 36% indicate
28
29 90 that others could easily access their data, approximately 75% agreed that they would
30
31 91 use other researcher’s datasets if easily accessible – these findings are also
32
33 92 supported by others (Federer et al., 2015; Hickson et al., 2016).
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39 93 ***How can researchers be encouraged to share data?***

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41 94 Encouraging data sharing amongst the scientific community and perhaps more
42
43 95 importantly, understanding what is “ideal” and what is the “reality” of data sharing is a
44
45 96 highly complex and contextual challenge (Bezuidenhout, 2019). In an extensive
46
47 97 review of the literature only one evidence-based incentive for data sharing was
48
49 98 identified (Rowhani-Farid et al., 2017). This was a digital badge created by the
50
51 99 Center for Open Science and tested in the Journal of Psychological Science. The
52
53 100 journal editorial team awarded badges to those authors who voluntarily applied and
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55 101 proved they met the criteria for open data and open materials upon article
56
57
58 102 acceptance. Sharing rates greatly improved over three years with the introduction of
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3 103 the digital badge (1.5% to 39.4%), but upon review, data and materials had
4
5 104 somehow disappeared from public view (Kidwell et al., 2016). Several other
6
7 105 evidence-based strategies were identified, most were technological strategies
8
9 106 (~75%) such as the introduction of data systems to manage and store data, and
10
11 107 others included collaborative data environments and workshops, implementation of
12
13 108 data sharing policies, and an open data campaign. However, many strategies lacked
14
15 109 good quality empirical data of their effectiveness.
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20 110 Conceptual models of how both institutional and individual drivers influence
21
22 111 researcher's data sharing behaviours, indicate the pivotal role that institutions play in
23
24 112 influencing open researcher practices (Ali-Khan et al., 2017; Fecher et al., 2015;
25
26 113 Kim, 2012). The dynamic relationship between the willingness to share data and the
27
28 114 actual sharing of data is largely motivated by rational self-interest rather than pure
29
30 115 altruism (Ali-Khan et al., 2017; Fecher et al., 2015; Levin and Leonelli, 2017; Levin et
31
32 116 al., 2016). The highly competitive nature of research and the importance of
33
34 117 maintaining strong academic metrics, mean that many fear they will miss out on
35
36 118 receiving attribution or credit (Anderson and Schonfeld, 2009; Antman, 2014;
37
38 119 Federer et al., 2015; Spallek et al., 2019). A review of the principles and norms of
39
40
41 120 data sharing in international health research identified four overarching themes: (1)
42
43 121 societal benefits and value; (2) distribution of risk, benefit and burden; (3) respect for
44
45 122 individuals and groups; and (4) public trust and engagement (Kalkman et al., 2019).
46
47
48 123 These themes are important to consider for data governance frameworks, data
49
50 124 management and sharing policies, and data processes and tools specific to each
51
52 125 research context. Observational studies that have identified patterns and barriers to
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54 126 data sharing are plentiful, but whilst these provide useful background knowledge,
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56 127 they do not provide evidence of what can be done to increase data sharing. The
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3 128 development of successful interventions must be underpinned by local evidence and
4
5 129 rigorous theoretical constructs, to facilitate behaviour change and provide
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8 130 explanation for the mechanism of change.
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10 11 131 ***Understanding behaviours that influence data sharing***

12
13 132 The use of theoretical frameworks in the design and evaluation of interventions has
14
15 133 been increasingly highlighted by implementation researchers (Eccles et al., 2005;
16
17 134 Kok et al., 2016; Michie and Johnston, 2012; Michie et al., 2005). For the first time,
18
19
20 135 this study will apply established theories to understand behaviours that influence
21
22 136 data sharing of health researchers. The two models to be employed are the
23
24 137 Behaviour Change Wheel (BCW) and the Theoretical Domains Framework (TDF).
25
26
27 138 The BCW is a validated model produced through the synthesis of many behaviour
28
29 139 change theories. It is commonly used to analyse, and design behaviour change
30
31
32 140 interventions (Michie et al., 2014). At the centre of the wheel are three core
33
34 141 components: capability, opportunity and motivation (collectively known as COM-B).
35
36 142 These components interact to produce “behaviour” and may explain the data sharing
37
38
39 143 behaviours of researchers who have different capabilities and opportunities to
40
41 144 change behaviour, regardless of their motivation (Michie et al., 2014; Michie et al.,
42
43 145 2011). The middle ring comprises of nine intervention functions and the outer ring
44
45 146 seven policy-driven strategies (Figure 1). The three key steps to using the BCW to
46
47
48 147 design behaviour change interventions includes: (1) understanding the behaviour
49
50 148 (COM-B); (2) identifying intervention options (middle ring); and (3) identifying content
51
52
53 149 and implementation options (outer ring).
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59 151 [Insert Figure 1 about here]
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152

153 In addition, the TDF is based on psychological and organisational theories to guide
 154 analysis and implementation of evidence-based practice (Michie et al., 2005). The
 155 TDF system consists of 14 domains that categorise influences on behaviour and are
 156 mapped to the COM-B components of the BCW in the analysis and design of
 157 targeted interventions (Box 1) (Atkins et al., 2017; Cane et al., 2012). The BCW and
 158 TDF have both been used to analyse and design behavioural change interventions in
 159 a variety of health settings, such as: reducing sugar free intake in adults (Rawahi et
 160 al., 2018), implementing telemedicine consultations for paediatric care (Bele et al.,
 161 2019), refining injury management in hospitals (Curtis et al., 2017), and
 162 understanding physical activity in overweight and obese pregnant women (Flannery
 163 et al., 2018). Despite the current shift towards more open data in research, there are
 164 seemingly no theoretically informed explorations; our understanding is limited to
 165 pragmatic reports.

166

167 **Box 1.** Mapping of the TDF domains to the COM-B model (Atkins et al., 2017).

TDF domain	COM-B component
Behavioural Regulation; Cognitive and Interpersonal Skills; Knowledge; Memory, Attention and Decision Processes	Psychological Capability
Physical Ability (Skills)	Physical Capability
Environmental Context and Resources	Physical Opportunity
Social Influences	Social Opportunity

Beliefs About Capabilities; Beliefs About Consequences; Emotion; Goals; Intentions; Optimism; Social/Professional Role and Identity	Reflective Motivation
Reinforcement; Emotion	Automatic Motivation

168

169 ***Study objectives***

170 The objective of this study was to determine the key behaviours that influence data

171 sharing practices among researchers, to inform the design of targeted behaviour

172 change interventions. The specific aims include:

173 a) Describe the current data sharing behaviours of health researchers using a

174 qualitative descriptive design.

175 b) Conduct a behavioural diagnosis of researcher data sharing behaviours using

176 the TDF and COM-B model.

177 c) Identify target behaviours and characterise intervention functions likely to be

178 most effective at changing target behaviours.

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3 **179 Method**

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6 **180 Study design and recruitment**

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8 181 A cross-sectional survey study was conducted to evaluate the data management
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10 182 practices of health researchers from one research institute at Griffith University,
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12 183 Australia. Full study methods and results have been previously published (Krahe et
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14 184 al., 2019a). The present study employed mixed-methods analysis to a selection of
15
16 185 the survey data (not previously reported) (Sandelowski, 2000). A copy of the survey
17
18 186 questions used in the analysis are available as Online Supplemental Material. This
19
20 187 study and all documentation received ethical approval from the Griffith University
21
22 188 Human Research Ethics Committee on 3 July 2017 (Reference number 2017/457).
23
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26
27 189 Participants were eligible if they were employed at the university in a permanent,
28
29 190 temporary or casual appointment and were actively involved in research. Potential
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31 191 participants (n = 401) were identified via the membership database and approached
32
33 192 by means of email with a request to participate in our online survey. The initial email
34
35 193 was sent with a link to the survey. If no response was received within two weeks,
36
37 194 one reminder email was sent. All participants were recruited between July and
38
39
40 195 August 2017. LimeSurvey (GmbH, v1.9X, Hamburg Germany) was used to
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42
43 196 administer the survey

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46 **197 Data sharing behaviours of researchers**

47
48 198 The main outcome measures were derived from survey questions about researcher's
49
50 199 current data sharing practice, their willingness to share data, and responses to
51
52 200 statements designed to explore components of data sharing behaviours. Descriptive
53
54 201 statistics were used to express categorical variables as counts and percentages.
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56
57 202 Response options for questions about willingness to share data are dichotomised
58
59 203 into two categories: willing (and somewhat willing); and unwilling (somewhat

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3 204 unwilling or not at all willing). These were coded as: willing = 1, and unwilling = 2.
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5 205 While the original survey provided a neutral option (neither willing nor unwilling) it
6
7 206 was treated as “missing” in this analysis, as it does not provide any information about
8
9
10 207 the level of agreement to the statement. A paired-samples t-test was conducted to
11
12 208 compare willingness to share data by researchers before and after publishing. The
13
14 209 mean and 95% CI for the change in willingness is also given. Quantitative survey
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16
17 210 data are imported into SPSS (IBM version 25.0) and analysed using descriptive
18
19 211 statistics.

22 ***Behavioural analysis and diagnosis***

23
24 213 Survey data are coded based on the definitions of the TDF domains (Cane et al.,
25
26
27 214 2012) and exemplar quotes illustrating these were identified in this process.
28
29 215 Quantitative survey data are deductively mapped to the TDF domains and then to
30
31 216 behavioural components of the COM-B model. Discussion occurred with members of
32
33
34 217 the research team to ensure appropriate coding. Behavioural themes were identified
35
36 218 and categorised as barriers (requiring modification) or facilitators (needing
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38 219 enhancing).

41 ***Identify intervention functions to change target behaviours***

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43 221 Applying the BCW, a well validated and widely used framework of behaviour change
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45
46 222 (Michie et al., 2014), intervention functions that correlate with the TDF and COM-B
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48 223 component for each behaviour were identified. These intervention functions are the
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50 224 “active ingredients” of intervention strategies.
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225 **Results**

226 ***Participant characteristics***

227 A total of 81 researchers participated in the study. Only 77 (19.2%) sufficiently
228 completed section four of the survey (i.e. related to data sharing) and were included
229 in the analysis. The majority were members of academic staff (58.4%), working in
230 the discipline of medical sciences (32.5%), and had worked in research for more
231 than 10 years (57.0%) (Table 1). Almost one-quarter of respondents self-identified as
232 early career researchers (n = 16, 24.6%), with a median of 2.5-years since
233 completing their PhD (range = 0 to 12 years).

234

235 [Insert Table 1 about here]

236

237 To understand the data characteristics that researchers were working with,
238 respondents were asked to indicate where they typically sourced their research data
239 (Krahe et al., 2019b). A list of primary (information collected and processed by the
240 researcher) and secondary (information retrieved through pre-existing sources) data
241 sources were provided, with the most common being surveys (66.2%), interviews
242 (54.5%), and experiments (46.8%) (Figure 2).

243

244 [Insert Figure 2 about here]

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246 ***Data sharing behaviours of researchers***

247 Almost two-fifths of respondents (37.7%, n = 29) had ever shared data outside their
248 immediate research/project team. Of these, 65.5% (n = 19/29) shared data only after

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3 249 the research data had been published (Figure 3). Only 15.6% (n = 12/77) of
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5 250 researchers had ever shared their data publicly as: supplementary material in a
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7 251 journal (58.3%), through an institutional (41.7%) or discipline-specific (25%)
8
9 252 repository, at a conference (33.3%), on a personal or project website (16.7%), or
10
11 253 through direct data requests (8.3%) (results not tabulated). The motivations for
12
13 254 researchers that shared their data with others outside of the research project and
14
15 255 more publicly (i.e. open access) are presented in Figure 4(a) and (b).
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23 257 [Insert Figure 3 about here]

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26 258 [Insert Figure 4 about here]

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32 260 The attitudes of researchers towards data sharing was further explored through their
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34 261 willingness to share data at two time points: (1) before data had been published; and
35
36 262 (2) after data had been published. Figure 5 illustrates that overall researchers were
37
38 263 most willing (97.2% \pm 1.97, n = 69/71) to share data before it was published with
39
40 264 members of their research group, and least willing (24.5% \pm 6.2, n = 12/49) to share
41
42 265 data with the wider public. After data had been published, all respondents (100%, n =
43
44 266 71/71) were willing to share data within their research group, 91% \pm 3.8 (n = 51/56)
45
46 267 were willing to share with colleagues in their organisations, 89% \pm 4.2 (n = 49/55)
47
48 268 with colleagues in their field, and just over one-half (55.1% \pm 7.1, n = 27/49) with the
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50 269 wider public.
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58 271 [Insert Figure 5 about here]
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6 273 A significant increase in the willingness to share data with colleagues in the
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8 274 organisation (14.2%; 95% CI 4.8 to 23.7; $P < 0.01$), colleagues in the field (29%;
9
10 275 95% CI 16.6 to 41.4; $P < 0.0001$), and with the wider public (30.6%; 95% CI 17.2 to
11
12 276 43.9; $P < 0.0001$) after data was published, was observed.

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16 277 ***Barriers and facilitators to data sharing***

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18 278 Six barriers and four facilitators were identified across seven of the 14 domains of
19
20 279 the TDF, including: knowledge, skills, environmental context and resources, social
21
22 280 influences, professional role and identity, beliefs about capabilities and beliefs about
23
24 281 consequences (Table 2). Domains that were not identified included optimism,
25
26 282 intention, behavioural regulation, goals, emotion, memory or attention and decision
27
28 283 processes. The primary barriers identified were coded to knowledge, and beliefs
29
30 284 about consequence. Many participants indicated that protecting the confidentiality of
31
32 285 their data to ensure ethical sharing (82.4%) and having a lack of understanding of
33
34 286 how to share data (71%), were barriers to data sharing. The primary facilitators were
35
36 287 coded to social influences and beliefs about consequence, where a clear
37
38 288 understanding of the benefit of data sharing (77.9%), and trust in those requesting or
39
40 289 using the data (77.9%), promoted data sharing. These are described in more detail
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42 290 below.

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51 292 [Insert Table 2 about here]

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3 294 *Responses to capability measures*
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5 295 Researcher's psychological capabilities influenced their data sharing practices,
6
7 296 defined within the COM-B model as the capacity to engage in the necessary thought
8
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10 297 processes, such as comprehension and reasoning (Atkins et al., 2017).
11
12 298 Respondents identified that a lack of understanding in the data sharing process
13
14 299 deterred them from data sharing (71.0%) and they would be more motivated to share
15
16 300 data if they had a better understanding of the process. Another capability barrier was
17
18 301 the lack of skill to conduct the data sharing process, with 53.2% reporting that they
19
20 302 do not know how to share data and 62.3% did not know where or who to share it
21
22 303 with. In both instances, one-fifth of researchers were unsure whether they had the
23
24 304 skills or knowledge related to data sharing. *'I don't really understand the processes*
25
26 305 *around data sharing, and I have many concerns about how the data is treated,*
27
28 306 *where it ends up, how it is interpreted, etc'* (Participant 43).
29
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32

33 307 *Responses to opportunity measures*
34

35
36 308 Barriers and facilitators within the social and physical research environments of the
37
38 309 COM-B model shaped the opportunities for researchers to share their data. Social
39
40 310 opportunity refers to factors that influence the way that we think about things (i.e.
41
42 311 cultural norms and social cues), and physical opportunity is afforded by the
43
44 312 environment (i.e. time and location). To measure opportunity factors, participants
45
46 313 were asked questions about capacity, regulative pressures and social influences.
47
48 314 Many respondents (67.5%) advised that they did not have the appropriate physical
49
50 315 opportunity (i.e. time or resources) to prepare their data for sharing; however, many
51
52 316 would if it were a funding requirement (72.7%), institutional requirement (63.6%) or
53
54 317 journal requirement (59.7%). *'Preparing data to ensure it is not identifiable can be*
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3 318 *complex and problems may not be immediately obvious, e.g. institutions can be*
4
5 319 *identified by bed numbers, yet this can be important data' (Participant 71).*
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8 320 The notion that data should be shared to create greater impacts for the wider public
9
10 321 was explored through a measure of social opportunity. Respondents were more
11
12 322 willing to share data if they knew it had public benefit (77.9% agreed, 3.9%
13
14 323 disagreed and 18.2% were unsure).
15
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18 324 *Responses to motivation measures*
19

20 325 Several barriers and facilitators tapped into researcher's motivations, which are
21
22 326 defined as the brain processes which direct our decisions and behaviours. The
23
24 327 COM-B model differentiates between automatic motivation (i.e. emotions and
25
26 328 impulses), and reflective motivation (i.e. evaluations and plans). Survey questions
27
28 329 measured factors influencing motivation related to scholarly gain or risk,
29
30 330 responsibility, integrity of practice, and integrity of others. The first two questions
31
32 331 related to automatic motivation, involving emotional reactions and desires (i.e. wants
33
34 332 and needs) that drive states and reflex responses. Seventy percent of respondents
35
36 333 advised that they would be motivated to share their data if they were guaranteed
37
38 334 proper credit for its use; 66.2% if it increased the visibility or impact of their research.
39
40 335 Just over one-half of respondents (55.8%) did not know whether it was their
41
42 336 responsibility to share data. *'Why would I need to share my data, other than with my*
43
44 337 *team and potentially in publication...current practices appear sufficient?' (Participant*
45
46 338 *41).*
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53 339 Respondents had strong beliefs about the consequences of data sharing. This
54
55 340 referred to the integrity of practice, where 85.7% reported concern about protecting
56
57 341 the confidentiality of their data and 79.2% were concerned about the ethics of data
58
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3 342 sharing. Similarly, 77.9% indicated that they would be more willing to share data with
4
5 343 someone that they trusted. *'Where it was not considered ethically appropriate to do*
6
7 344 *so, or I was compelled to do so by the institution without a valid explanation of why; I*
8
9 345 *would be deterred from sharing'* (Participant 50).

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11
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13 346 Lastly, reflective motivation was assessed. About one-half were concerned that their
14
15 347 research would be stolen (53.2%), 79.2% were concerned it might be misinterpreted
16
17 348 or misused, and 75.3% wanted to protect their intellectual property. *'People, when*
18
19 349 *pushed to the extreme for research and publications are happy to steal other's ideas*
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21 350 *and would be quite capable of stealing their data'* (Participant 80).

22 351 **Identifying intervention functions and target behaviours**

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27 352 Following application of the BCW, intervention functions were identified to address
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29 353 barriers and facilitators (Table 2). It is possible to see how one intervention function
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31 354 may serve to influence more than one behaviour. For example, incorporating
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33 355 modelling techniques (i.e. demonstration of the behaviour) would address five of the
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35 356 seven behaviours. Intervention functions that were not aligned to the target
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37 357 behaviours, include incentivisation and coercion.

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42 358 Considering that behaviours do not occur in isolation of one another, the research
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44 359 team critically reviewed each behaviour and where appropriate grouped co-
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46 360 dependent behaviours. These were: (1) understanding the data sharing process
47
48 361 (knowledge) and knowing how, where and who to share with (physical skills); and (2)
49
50 362 protecting the confidentiality of data and safeguarding intellectual property from
51
52 363 being stolen or data being misinterpreted or misused (both beliefs about
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54 364 consequences). This resulted in eight key behaviours that influence data sharing and
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56 365 should be addressed through targeted intervention strategies (see Box 2).

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3 366 **Box 2.** Target behaviours to promote data sharing in health research.
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- 6 1. The researcher understands and is competent to conduct data sharing
7 practices.
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- 9 2. The researcher prioritises their time and resources to prepare data for
10 sharing.
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- 12 3. The researcher shares data to meet funding, institutional and/or journal
13 requirements
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- 15 4. The researcher shares data for public and/or patient benefit.
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- 17 5. The researcher receives credit and increased visibility of their research
18 following data sharing.
19
- 20 6. The researcher understands data sharing responsibilities.
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- 22 7. The researcher understands the way in which the confidentiality and
23 safety of data are protected and how to share data ethically.
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- 25 8. The researcher shares data with trusted and credible people.
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368 Discussion

369 This study applied a systematic and theoretical process to identify barriers and
370 facilitators that influence data sharing practices among researchers. It has also filled
371 a gap in the research by conceptualising the findings more broadly within
372 researcher's capability, opportunity, and motivation, and provides a more granular
373 understanding of behaviours which influence data sharing. Application of the BCW
374 and TDF added substantial strength to the study, grounding it in evidence-based
375 theory.

376 A key observation of this study was that while several individual behaviours can be
377 targeted to influence data sharing, the interaction between these behaviours is
378 complex, and single solutions to single behaviours are unlikely to suffice. Strategies
379 to resolve specific barriers may not advance data sharing if related barriers are not
380 addressed, or if fundamental barriers are unchanged; many of the barriers and
381 facilitators were opposites of one another or dependent on one another. For
382 example, in terms of the societal benefits and value, the public and patient benefit to
383 data sharing was an important facilitator, while a lack of understanding the duty to
384 share data inhibits the behaviour. To this end, it is commonly recognised that there
385 can be no "one size fits all" when it comes to a data sharing strategy. In most cases,
386 disciplinary or user communities need to develop their own data sharing standards
387 and practices that suit their needs, and the combinations of different factors need to
388 be considered rather than looking at individual barriers and facilitators in a stand-
389 alone fashion (Zuiderwijk and Spiers, 2019). The best practices from one discipline
390 cannot simply be transferred to other disciplines without considering the unique
391 characteristics and addressing the individual challenges. For instance, atmospheric
392 science and oceanography have well-developed traditions of open access, whereas

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2
3 393 ecology, medicine and social sciences do not (Tenopir et al., 2011; Zuiderwijk and
4
5 394 Spiers, 2019).

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8 395 In developing the next steps of our data sharing strategy, we recognise that
9
10 396 information generated or collected from health research may contain large volumes
11
12 397 of highly sensitive data, have explicit privacy and/or security considerations, or a
13
14 398 degree of commercialisation. In order to protect privacy, confidentiality and respect
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16 399 the terms under which participants consented to take part in the original study, data
17
18 400 needs to be planned, collected and stored in such a way that is appropriate. In some
19
20 401 cases, it may not be possible to share or reuse data. This is explored within the
21
22 402 larger cohort of this study, where the majority (65.5%) of researchers obtain specific
23
24 403 consent for their studies and collect data in a non-identifiable format (69.0%), limiting
25
26 404 it for use in the immediate project and not permitting data linkage or sharing for
27
28 405 future projects (Krahe et al., 2019a). Considering this, it is now more important than
29
30 406 ever to educate researchers about planning their research to enable sharing and
31
32 407 reuse which involves the incorporation of considered and appropriate consent
33
34 408 (Cheah et al., 2015; O'Keefe and Connolly, 2010). This is one example of a
35
36 409 contextual challenge that presents within the health research discipline that must be
37
38 410 reflected within the strategy; perhaps learning from other disciplines where sharing is
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40 411 more commonplace.

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43 412 Applying the COM-B model raised our awareness of the significant barriers to
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45 413 perceived capability, opportunity and motivation to data sharing, but also provided
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47 414 guidance on the most appropriate methods needed to elicit behaviour change. We
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49 415 believe that this behavioural approach to intervention design will allow more informed
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51 416 decisions about which “active ingredients” to include in the intervention strategy and
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53 417 will assist in selecting the right mix of strategies to drive behaviour change. The
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3 418 capability, opportunity and motivations of individual researchers to share data are
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5 419 strongly influenced by contextual factors (i.e. institutional policies and regulations on
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7 420 sharing data or the degree to which sharing data is encouraged by supervisors and
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9 421 colleagues) and hence cannot be isolated from institutional context.

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13 422 The next step in this study is to select intervention functions aimed at overcoming the
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15 423 barriers and enhancing the facilitators identified. Research team members with
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17 424 expertise in data sharing best practices, intervention design and behaviour change,
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19 425 will consider which intervention functions are most appropriate or have the best
20
21 426 potential chance of success, and how they would best be delivered. This process will
22
23 427 be guided by the APEASE criteria (Affordability, Practicability, Effectiveness/Cost-
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25 428 Effectiveness, Acceptability, Safety/Side Effects, Equity) to make context-based
26
27 429 decisions (Michie et al., 2014). Interventions will be designed that aim to reduce the
28
29 430 barriers and increase the likelihood (facilitators) that researchers will partake in data
30
31 431 sharing practices. While several interventions could be applied, a pragmatic
32
33 432 approach will be taken, in combination with further stakeholder consultation prior to
34
35 433 piloting. The effectiveness of the selected interventions will be tested using mixed
36
37 434 methods to evaluate which components are the most effective in changing
38
39 435 behaviour.

46 436 ***Implications of our findings***

47
48 437 The advancement of science thrives on the sharing and accessibility of data, but
49
50 438 despite this, it is yet to become common practice in research. A major strength of
51
52 439 this study is that a systematic approach was applied which strengthens the
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54 440 theoretical foundations towards the development of data sharing interventions in the
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56 441 research setting. It contextualises two important factors of research best practice and
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3 442 behaviour change, and while the process was time intensive, it provides a foundation
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5 443 for the next stage of intervention design, implementation and evaluation.
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8 444 ***Limitations of this study***
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10 445 In this study a possible limitation is the potential lack of generalisability of the results,
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12 446 which in part is due to the limited survey completion rate. It is feasible that factors
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14 447 perceived as important for this cohort could be different in other settings with varying
15
16 448 attitudes, capabilities and/or research culture. While our outcomes are likely to be
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18 449 representative, or at least comparable to similar health research settings, it is
19
20 450 important to consider the contextual intricacies that influence behaviour. For
21
22 451 example, our cohort is predominantly (57.0%) representative of researchers with 10
23
24 452 or more years of experience; where compared to researchers with less experience
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26 453 (i.e. 1-5 years or 5-10 years), may likely hold different attitudes and practices based
27
28 454 upon their exposure to and agility towards data sharing. Central to the recent Wiley
29
30 455 Survey is growing researcher demand for open access and open research, where
31
32 456 older, more experienced researchers require different forms of open research
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34 457 centred around guidelines for the sharing of data and improved measurement of the
35
36 458 impact of research (Roscoe, 2020). We recommend using this study as a guide to
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38 459 understand data sharing behaviours but advise developing localised intervention
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40 460 strategies for different contexts. Another limitation is the iterative nature of the
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42 461 process, which is often navigated in a bi-directional state due to ongoing consultation
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44 462 and further consideration or refinement. Despite this, it is the first study to provide a
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46 463 behavioural analysis of the data sharing practices of health researchers and the
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48 464 rigorous method used merits consideration.
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3 **465 Conclusion**
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5 466 This is to our knowledge, the first study that has assessed and quantified barriers
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7 467 and facilitators to data sharing in health research. Using a theoretically informed
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10 468 methodology, we have identified that while the barriers to improving data sharing
11
12 469 behaviours are considerable, opportunities for improvement do exist. Interventions
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14 470 that address specific behaviours are important towards motivating participation in
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16 471 data sharing and open researcher practices. It is hoped that the process we have
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18 472 described may be used by others working in research, health information/informatics,
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20 473 library and information services, and/or those interested in the adoption and
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23 474 acceleration of research practices, capabilities and solutions.
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3 **475 Author's contributions**
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5 476 All authors meet the criteria for authorship and contributed to the conceptualisation
6
7 477 and design of this study. Michelle Krahe (MK) was responsible for the acquisition,
8
9 478 analysis of data and drafted the article. Malcolm Wolski (MW), Sharon Mickan (SM)
10
11 479 and Julie Toohey (JT) aided in the interpretation of the data. Paul Scuffham (PS) and
12
13 480 Sheena Reilly (SR) provided critical editing, and final approval.
14
15
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17

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19

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21
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29
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34 **487 Data availability statement**
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36 488 The data that support the findings of this study are openly available in Figshare at:
37
38 489 <https://doi.org/10.6084/m9.figshare.11521890.v1>
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622 **Tables and figures**

623

624 **Table 1.** Characteristics of respondents (n = 77).

Characteristics	n	%
Appointment type		
Academic	45	58.4
Adjunct	4	5.2
Research Fellow	12	15.6
Research Assistant	4	5.2
Postgraduate Student (PhD)	12	15.6
Health discipline		
Allied Health Science	10	13.0
Applied Psychology	14	18.2
Human Services and Social Work	5	6.5
Medical Sciences	25	32.5
Medicine	4	5.2
Nursing and Midwifery	11	14.2
Pharmacy	2	2.6
Other ^a	6	7.8
Research Experience (years) ^b		
1-5	9	13.8
5-10	19	29.2
> 10	37	57.0

625 ^a researcher working for the Institute, not one specific area626 ^b excluding postgraduate students (n = 65)

627 **Table 2.** Behavioural analysis of data sharing among health researchers using the TDF and BCW.

TDF domain ^a	COM-B model	Perceived barrier / facilitator to data sharing among health researchers	Intervention function ^b
Knowledge	Psychological Capability	Barrier: Lack of understanding how to share data	Education and training
Physical Skills	Physical Capability	Barrier: Lack of experience (i.e. how, where and who)	Training and enablement
Environmental Context and Resources	Physical Opportunity	Barrier: Resources (i.e. time) are inadequate to prepare data for sharing Facilitator: Appropriate institutional, funding or publication incentives/requirements are needed	Training, restriction, environmental restructuring and enablement
Social Influences	Social Opportunity	Facilitator: Understanding the public or patient benefits of data sharing	Restriction, environmental restructuring, modelling and enablement

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Professional	Automatic	Facilitator: Improving visibility of research and ensuring credit (for use) is received	Education, persuasion and modelling
Role and Identity	Motivation		
Beliefs About Capabilities		Barrier: Uncertainty about who is responsible for data sharing	Education, persuasion, modelling and enablement
	Reflective	Barrier: Protecting data confidentiality in the absence of adequate sharing guidelines	
Beliefs About Consequences	Motivation	Barrier: Safeguarding intellectual property from being stolen, or data being misinterpreted or misused	Education, persuasion and modelling
		Facilitator: Trust in those requesting or using the data	

628 TDF = theoretical domains framework; BCW = behaviour change wheel; COM-B = capability, opportunity and motivation.

629 ^a Definition of TDF domains adapted from Atkins et al. (2017): Knowledge: An awareness or existence of something; Physical Skills:

630 An ability or proficiency acquired through practice; Environmental Context and Resources: A person’s situation or environment;

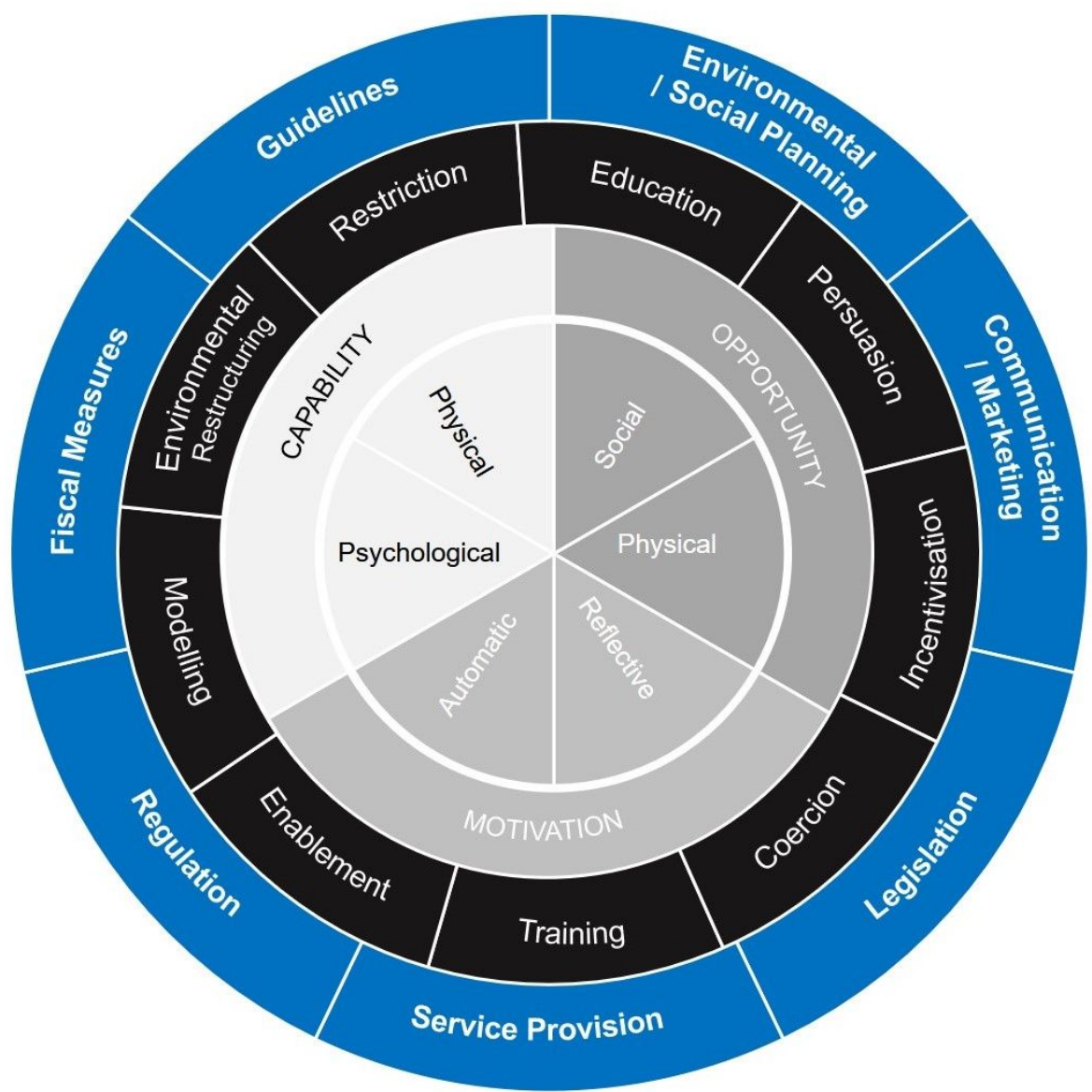
631 Social Influences: Process that can change their thoughts, feelings, or behaviours; Beliefs About Capabilities: Acceptance of the

632 truth, reality, or validity about an ability, talent or facility that can be used constructively; Beliefs About Consequences: Acceptance

633 of the truth, reality, or validity about outcomes of a behaviour in a given situation. TDF domains not covered: optimism;

634 reinforcement; intentions; goals; memory, attention and decision processes; emotion, behavioural regulation. ^b Definition of

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3 635 intervention functions (adapted from Michie et al. (2011)): Education: Increase knowledge or understanding; Persuasion: Using
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5 636 communication to induce positive or negative feelings or stimulate action; Training: Imparting skills; Restriction: Using rules to
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7 637 reduce the opportunity to engage in the target behaviour; Environmental Restructuring: Changing the physical or social context;
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9 638 Modelling: Providing an example for people to aspire to or imitate; Enablement: Increasing means/reducing barriers to increase
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11 639 capability or opportunity.
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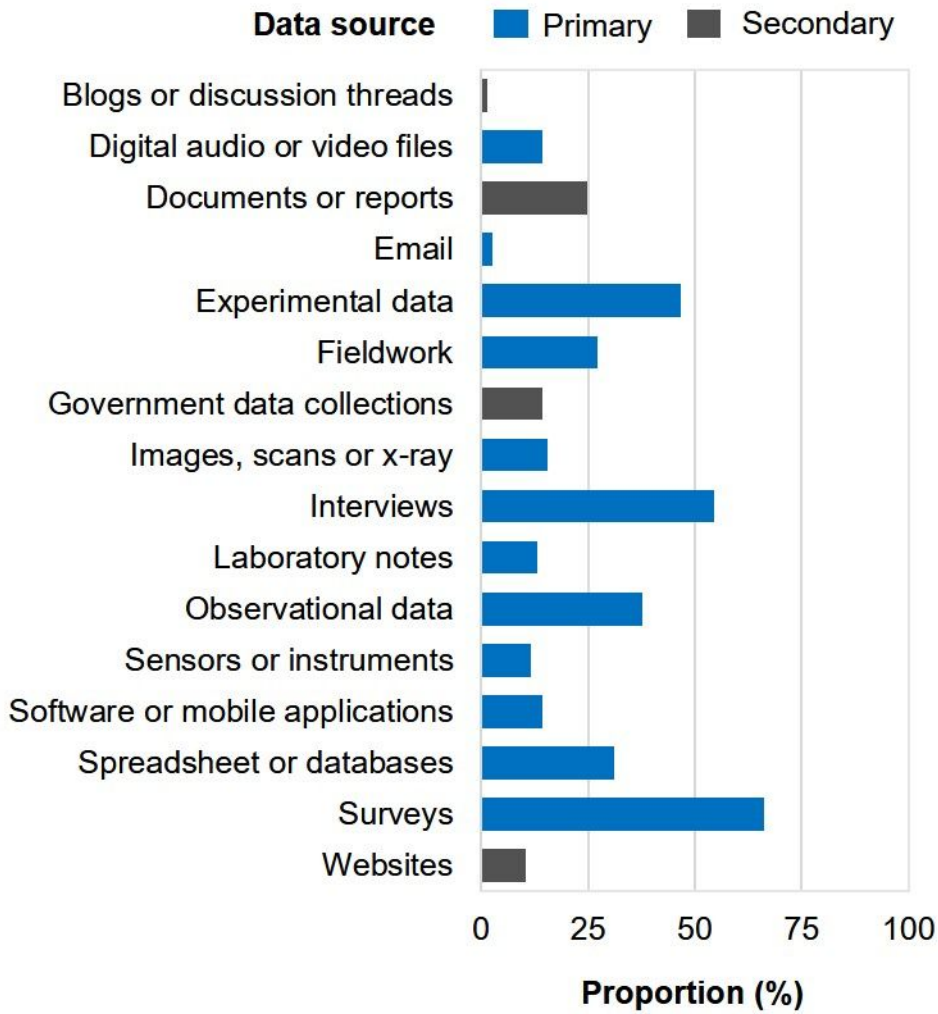


Sources of behaviour
 Intervention functions
 Policy categories

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641 **Figure 1.** The Behaviour Change Wheel. Adapted from Michie et al. (2011)

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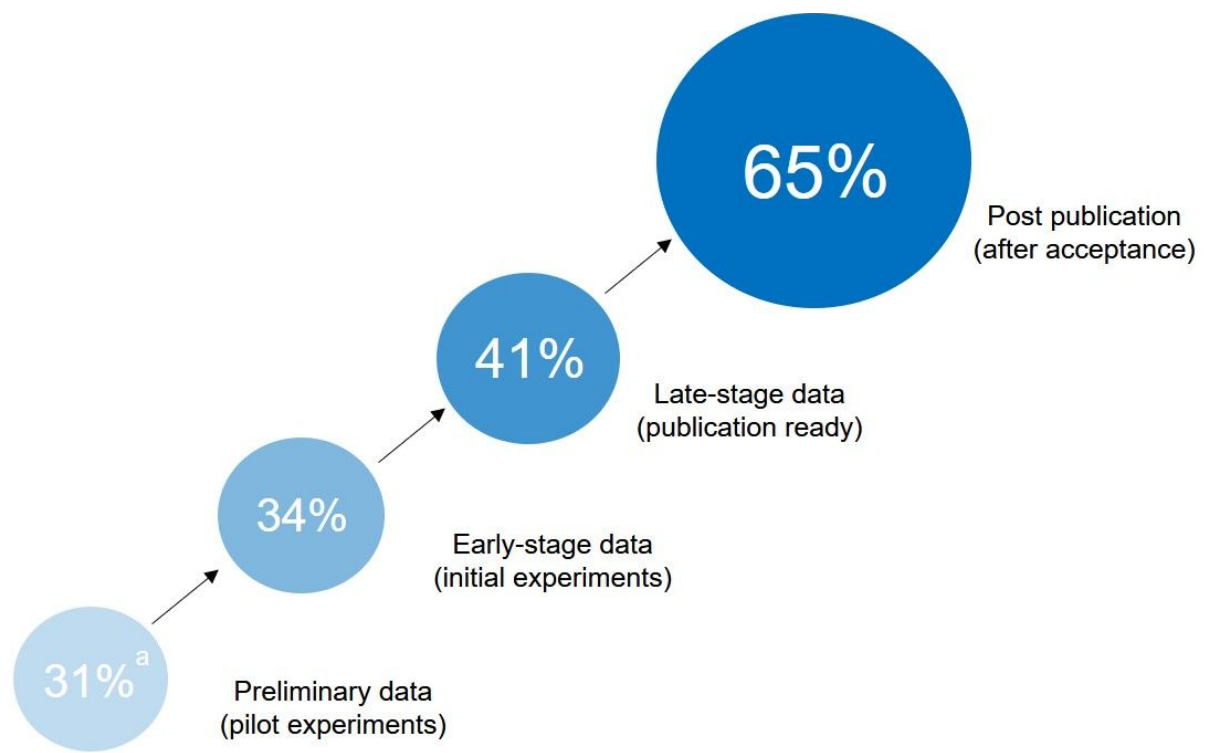


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643 **Figure 2.** Places where researchers typically source their data.

644 Note: Respondents could select multiple responses.

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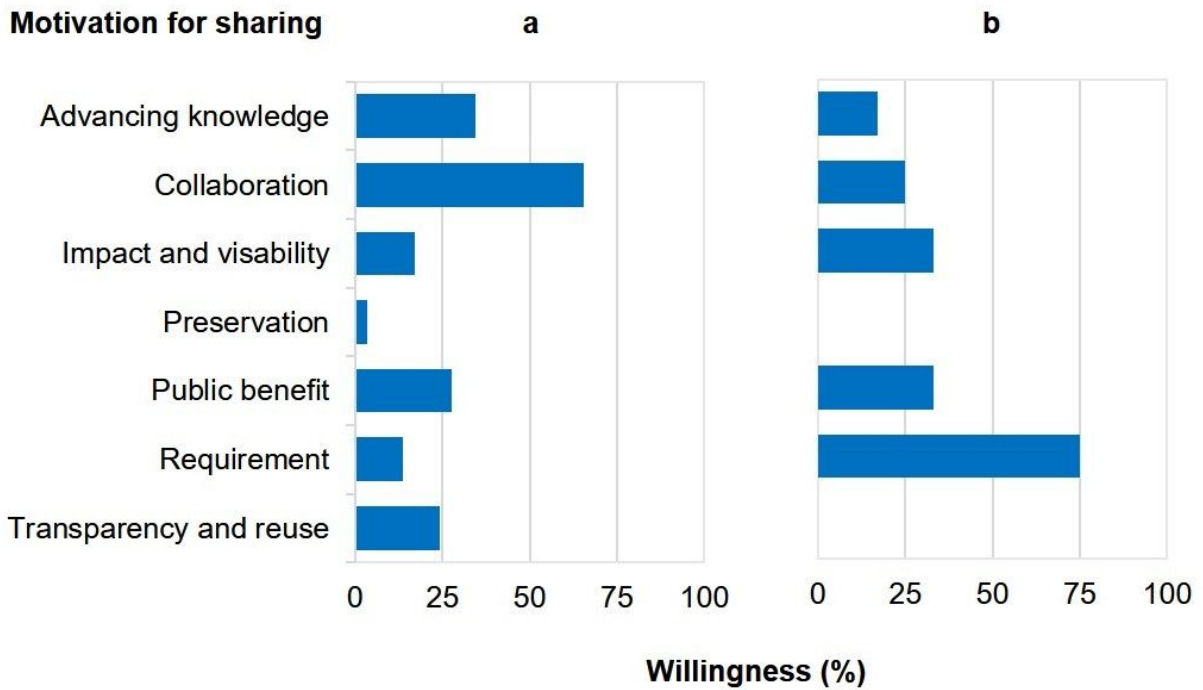


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646 **Figure 3.** The proportion (%) of researchers who share their data external to the
647 research project, as distributed by research data timepoints.

648 ^aData are calculated for researchers who had ever shared data external to the
649 research project (n = 29).

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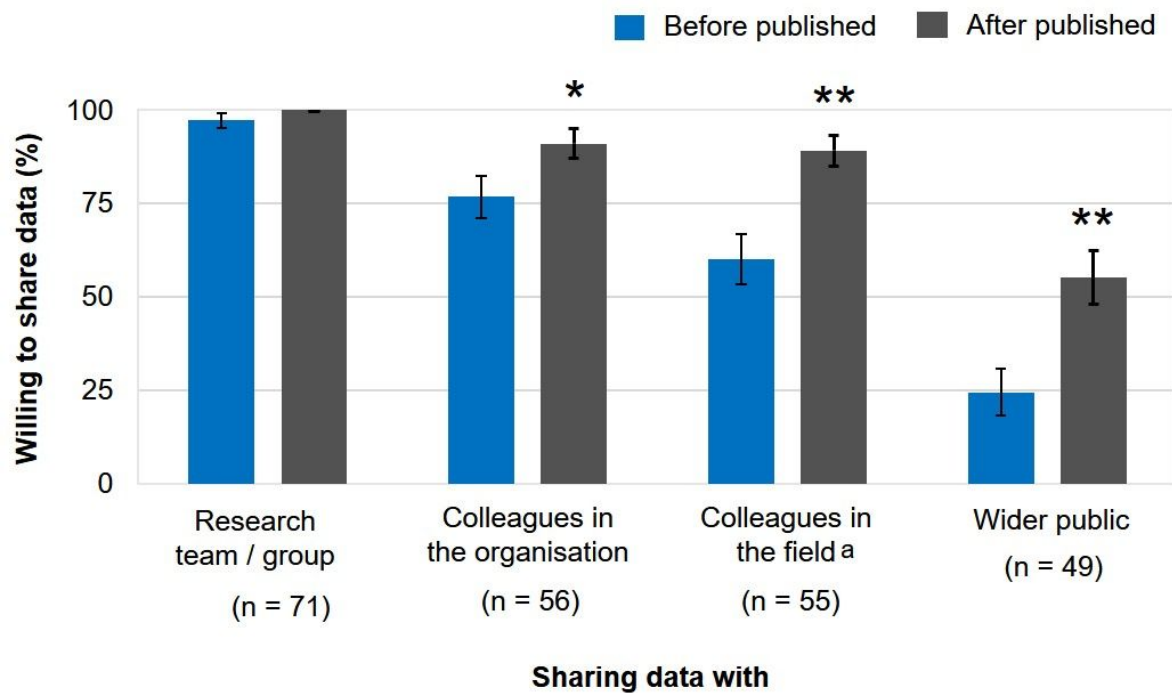


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651 **Figure 4.** What motivates researchers to share their data with: (a) external

652 individuals to the research project and, (b) the wider public.

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654 **Figure 5.** Researcher willingness (mean \pm SEM) to share research data.

655 ^aIncludes internal and external colleagues; n = represents the denominator excluding
 656 “neutral”; *correlation is significant at the 0.05 level (2-tailed); **correlation is
 657 significant at the 0.001 level (2-tailed).

Supplemental Material

Summary of research data management survey questions and response options used in this study.

Survey Question	Response Options
Q1. Have you ever shared research data outside of your project team?	Yes / No / Unsure
^Q1.1. If yes, what kind of data was it?	4 options: Draft or preliminary data (pilot experiments); early-stage data (initial experiments); late-stage data (publication ready); post-publications data (shared after manuscript was accepted) + open-ended
^Q1.2. If yes, why did you choose to share your research data?	7 options: advancing knowledge; collaboration with colleagues; increase the impact and visibility of my research; preservation of the data; public benefit; recommended or required by the funder; transparency and reuse + open-ended

<p>1 2 3 4 5 6 7 8</p> <p>Q2. Have you ever shared research data publicly?</p>	<p>Yes / No / Unsure</p>
<p>9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26</p> <p>^Q2.1. If yes, where did you make your data publicly available?</p>	<p>6 options: as supplementary material in a journal; institutional repository; discipline-specific repository; personal, institutional or project website; informal paths or upon request; at a conference +open-ended</p>
<p>27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47</p> <p>^Q2.2. If yes, why did you choose to share your research data?</p>	<p>7 options: advancing knowledge; collaboration with colleagues; increase the impact and visibility of my research; preservation of the data; public benefit; recommended or required by the funder; transparency and reuse + open-ended</p>
<p>48 49 50 51 52 53 54 55 56 57 58 59 60</p> <p>Q3. <u>Before</u> you publish your research, how willing are you to share your data with...?</p> <p>a) Members of your research team/group</p> <p>b) Colleagues at the university</p> <p>c) Colleagues in your field</p>	<p>5-point Likert scale: definitely willing; somewhat willing; neither willing nor unwilling; somewhat willing; not at all</p>

d) The public at large	willing (dichotomised into two categories: willing; unwilling)
<p>Q4. <u>After</u> you publish your research, how willing are you to share your data with...?</p> <p>a) Members of your research team/group</p> <p>b) Colleagues at the university</p> <p>c) Colleagues in your field</p> <p>d) The public at large</p>	<p>5-point Likert scale: definitely willing; somewhat willing; neither willing nor unwilling; somewhat willing; not at all willing (dichotomised into two categories: willing; unwilling)</p>
<p>Q5. How much do you agree with the following statements...?</p> <p>a) I do not know where to share my data or who to share it with</p> <p>b) I do not know how to share my data</p> <p>c) I don't have the time or resources to prepare my data for sharing</p> <p>d) I don't know if it is my responsibility to share the data</p> <p>e) I am concerned about given proper credit for the use of the data</p> <p>f) I am concerned that my research will be stolen</p> <p>g) I am concerned about the misinterpretation or misuse of the data</p>	<p>5-point Likert scale: strongly agree; somewhat agree, neither agree or disagree; somewhat agree; strongly agree</p>

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<p>h) I am concerned whether it is unethical to share the data</p> <p>i) I want to protect my intellectual property</p> <p>j) I want to protect the confidentiality of the data</p>	
<p>Q6. Would you be motivated to share your research data if...?</p> <p>a) It was a funding requirement</p> <p>b) It was an institutional requirement</p> <p>c) It was a journal requirement</p> <p>d) There was a public/patient benefit</p> <p>e) The impact and visibility of my research increased</p> <p>f) I was guaranteed proper credit for its use</p> <p>g) I had absolute trust in the person requesting the data</p> <p>h) I had a better understanding of the data sharing process.</p>	<p>Yes / No / Unsure</p>

^Multiple responses to question could be selected by respondent