Giving Science Innovation Systems a ‘Nudge’

Kirsty de Jong, Urs Daellenbach, Sally Davenport, Jarrod Haar and Shirley Leitch

> *“Decision makers do not make choices in a vacuum. They make them in an environment where many features, noticed and unnoticed, can influence their decisions. The person who creates that environment is…a choice architect.”*
>
> Richard Thaler, Cass Sunstein & John Balz
> Authors of “Choice Architecture”,
> in *The Behavioral Foundations of Public Policy*

In this article we consider the role that contextual factors play in science innovation systems - that is, the choice architecture, that influences the orientation and outcomes of publicly-funded research. More specifically, we examine how choice architects, particularly policymakers and funding administrators, can affect the decision-making behaviour of researchers. The context for today’s science innovation systems continues to shift as governments seek solutions to the world’s “grand societal challenges” such as climate change and ageing populations, in addition to greater and more demonstrable impact from funded research. This means that the assumptions of “basic research [being] performed without thought of practical ends” (Bush, 1945) that have shaped such projects, actually run counter to the growing expectations of greater commercialisation and use of multidisciplinary mission-led approaches. We argue that a closer examination of the choice architecture of publicly-funded research is required to understand and address how these potentially conflicting objectives may be pursued most productively through interventions that could form the basis of a novel, behaviourally-based toolkit for science innovation policy.

Introduction

Choice architecture “refers to the practice of influencing choice by changing the manner in which options are presented to people” (Samson, 2018: 125). Choice architecture can be thought of as an aggregate of “nudges”, which Thaler and Sunstein define as “any aspect of the choice architecture that alters people’s behaviour in a predictable way without forbidding any options or significantly changing their economic incentives. To count as a mere nudge, the intervention must be easy and cheap to avoid” (2008: 6). Choice architecture has its roots in behavioural economics, which as a discipline, incorporates evidence from psychology about the effect of innate human response and experience on economic decisions. Behavioural economics developed to address the perceived inefficacy of theories of rationality that featured prominently in the economics literature; the view that people make consistently rational decisions was seen as incompatible with a much more complex reality where a multitude of factors - such as biases and heuristics - undermine the likelihood of this occurring (Thaler & Sunstein, 2009; Samson, 2018).

Science researchers appear to face a similar conundrum with regard to governments’ and policymakers’ prevailing views of how science innovation develops (Jahnke, 2015). While behavioural economics acknowledges that people are operating in increasingly complex everyday environments that impact the way they make decisions (Thaler & Sunstein, 2009), the same phenomenon can be observed in science innovation systems today (Whitley et al., 2018; Dowling, 2018; Van de Ven et al., 2017; Nicholls, 2017). Complexity in science innovation systems is a corollary of calls for more interdisciplinary, mission-orientated approaches to address grand societal challenges (Robinson & Mazzucato, 2018), and greater governmental pressure to see demonstrable impact from their investment in science research (e.g., MBIE, 2015; Dowling, 2018). The negative implications this has for researchers’ experience of science management and administration within the innovation system has been recognised (Whitley et al., 2018; Dowling, 2018; Van de Ven et al., 2017; Nicholls, 2017). Despite this, there has been limited change made to the processes for identifying projects and funding research.

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Using a behavioural science lens, we are able to shed new light on how elements of the science innovation system - namely government policy and research funding - might influence research orientation and outcomes in a way that undermines goals relating to mission-led science and impact. Using choice architecture as a framework for our argument and analysis, we highlight how a combination of interventions in science research management and administration could be used to reorientate research in such a way that it supports the aforementioned aims, with a view to these interventions forming the basis of a novel behaviourally-based toolkit for science innovation policy.

Current Science Innovation Systems: Understating Complexity of Basic Research

Science innovation systems (and more recent reference to innovation ecosystems: Jackson, 2011), both national and regional, relate to "the linkages among the actors involved in innovation" (OECD, 1997: 9). It involves interaction between these actors (public and private) and the activities (creating, changing and diffusing) they undertake to generate valuable new technology and knowledge (Freeman 1994; Lundval, 1992). Governments are motivated to invest and participate in science innovation systems because technological innovation has a positive impact on national wellbeing (Gluckman, 2015). Their involvement in science innovation processes typically includes (but is not limited to), setting the policies and priorities for innovation, and/or providing the funding for it. Presumably, this requires governments, and particularly policymakers, to have an accurate and pragmatic view of the innovation process. Counterintuitively, though, this appears often to not be the case (Van de Ven et al., 2017).

This gap in understanding exists because the "processes that encourage the development and adoption of game-changing innovations are more complex than the people creating government policies and practices consider" (Van de Ven et al., 2017: 94). An investigation of the views of over 3,700 American scientists (Pew Research Center, 2015) reported that "much of the public - and many politicians - do not have a general understanding of the scientific process; knowledge critical for smart decision-making in our increasingly technological society" (Jahnke, 2015: 1). This is problematic because governments and policymakers are most often the primary choice architects of science innovation processes: how they construct the policy and research funding arena will naturally exert both intended and unanticipated influence on research orientation and outcomes.

This problem can be in part attributed to the way in which Vannevar Bush conceptualised the innovation process in the United States of America's first attempt at an official innovation policy: his 1945 report *Science: The Endless Frontier* (Pielke, 2010). In this report, Bush, now "regarded as the architect of all government funding for university research" (Jahnke, 2015: 8), formalised the notion that the journey from science innovation to commercialisation progresses through an identifiable set of linear stages (Van de Ven, 2017). This view endures because of similarly structured, more contemporary frameworks like the technology readiness levels (TRLs); the innovation funnel (IfM, 2019); and the stage-gate model, the latter which many organisations now utilise to manage research and development, despite extant cautions against confining it within rigid, lock-step, linear, or bureaucratic processes (Cooper, 2008). These frameworks reflect not only a lack of understanding about the realities of the innovation process - characterised as it is by uncertainty, lags, and "multiple feedback loops in which the downstream activities of development and deployment generate both new problems and new knowledge that change the agendas of the upstream stages of research and development" (Van de Ven et al., 2017: 97) - but an optimism too. That this unpredictability and interplay can occur across "single [… or] multiple ... streams of scientific or technological development" (Ibid) only serves to increase the complexity involved; a factor under-acknowledged in these frameworks.

We argue that a broader effect of such frameworks tends to be the embedding of positive assumptions about linear transformations and the potential for sequential controlled resolution of uncertainties in science innovation research and development in the minds of policy and funding administrators. These assumptions manifest in the way granting agencies typically require reports to reflect distinct and progressive stages of research, and the way they allocate types of funding to research projects depending on the stage that they begin or intend to conclude, with different expectations attached for each. For example, basic research (TRL 1-3) is often happily devoid of the requirement to engage with or consider potential stakeholders, whose involvement is needed at later stages of development.

Undertaking research that involves complex, difficult to understand, and uncertain conditions, when funded via policies and processes that assume a linear, staged, controllable research endeavour, represents two conflicting sets of circumstances whose incompatibility we argue, can makes things harder for researchers. In addition, it can negatively affect research orientation and outcomes by impeding researchers' ability to deliver basic, let alone impactful, research. In the following sections, we explore in more depth the ways in which this can occur.

Influences on Innovation Orientation and Outcomes in Publicly Funded Research

1. Government policy
The relationship between government policy and science innovation is a long-standing one, with historical roots as deep as 18th century European imperialism. Bush's argument for a centralised government funding system in the USA led to the establishment of the National Science Foundation, with other countries successively following suit (Gluckman, 2015). This helped to 'entrench the concept of government patronage of scientific research' (Pielke, 2010: 923).

Government policy is understood to influence research orientation and outcomes in one of two ways: first, in a remedial sense; investing in areas neglected by the private sector. For example, because many businesses seek shorter term returns for their investments (for example, Lumpkin et al., 2010), this typically disincentivises them from investing in basic research where the outcomes are not known and deliverables less certain. To compensate for this, governments tend to invest in basic research and/or projects in the public's interest. Second, governments may use policy to catalyse more radical change in the direction of innovation research.

Setting science "missions" has become an increasingly common way of doing this, and missions have gradually evolved to reflect a democratisation of science, and a decentralisation of its orchestrating actors (Robinson & Mazzucato, 2018). In general, missions (past and present) have sought to align technological development to meet government goals (Robinson & Mazzucato, 2018). Mission-led science in the 20th century was used competitively by governments to progress their nation's health and wealth, particularly during periods of conflict (Gluckman, 2015). Governments would, in advance, identify their objective, desired outcome, and the technological enabler in the middle (for example, using a rocket to be the first country to land on the Moon). Contemporary missions differ in that they are more often applied to grand societal challenges whose effects extend beyond borders; involve unpredictable technological developments; are inherently complex; and are not amenable to solutions currently available (Robinson & Mazzucato, 2018), all characteristics which are associated with basic research. Such a combination of factors demands a more collective approach than has been employed in the past, as their inherent difficulty requires involvement from a wider cross-section of society (including industry), to provide access to a greater diversity of input (Kuhlmann & Rip, 2018; Robinson & Mazzucato, 2018). This has important implications for choice architects, as it is likely to require changes in how science and innovation are both managed and organised "at the societal/national systems level" (Robinson & Mazzucato, 2018: 938); with "technological, behavioural and systemic changes" (Mazzucato, 2016: 140), and a "willingness to explore varieties of extant and new approaches" (Kuhlmann & Rip, 2018: 448). Such changes are made possible by changes to policy.

2. Funding
One implication of a shifting policy landscape is its effects on research funding. Given this rise of "new constellations of innovation actors" (Kuhlmann & Rip, 2018: 448), researchers increasingly "have to share their authority over research goals with more varied sets of actors, many of which have developed strong expectations concerning research goals and are using their control of funding to exercise authority accordingly" (Whitley et al., 2018: 111). These actors, including public research councils, private foundations and charities, are made more powerful by the widespread downturn in public research grants, which has contributed to increasing the level of competition between researchers for funding (Whitley et al., 2018). Funding thus assumes more scope to be perceived as a coercive mechanism orientating research toward the outcomes that funders want. Indeed, research funding has been described as "a battleground for different agents with different strategies, and its structure will be a crucial element in the development of new forms of knowledge production" (Benner & Sandström, 2000: 301).

Actors, notably, will vary in how and to what extent they seek to design the conditions relating to research inputs, outputs, and methodologies. Clarity of conditions and expectations tends to be greater with industry grants and less so in the case of publicly-funded, socially-orientated science, especially when it is mission-led (Hottenrott &

Lawson, 2013). This variation reflects in part the social norms concomitant to each of these groups. In behavioural science, social norms are incredibly influential on behaviour (Gockeritz et al., 2010; Reynolds et al., 2014), as they govern how people behave in certain groups by communicating what that group deems acceptable (Samson, 2018). Descriptive norms *describe* "normal" behaviour, with normal being what the majority is generally understood to do. Injunctive norms are those "rules or beliefs as to what constitutes morally approved and disapproved conduct" (Reynolds et al., 2014: 2, citing Cialdini et al., 1990: 1015). In-group social norms originate from the social interplay of individuals already psychologically connected by pre-existing and mutual membership to a social group. Academic work has theoretically linked, using real world examples, how the established norms of different actors within science innovation systems have contributed to: a) funding models that support the interests of particular groups like research councils run by academics; and b) funding models that can challenge and seek to *change* the status quo to engender different research results. Norms represent a "dominant institutional order" (Benner & Sandström, 2000: 291), and are thus expressed through mechanisms like criteria, incentives and research evaluation, which can, in turn, impact expectations around administrative processes like review, reporting and approval (Benner & Sandström, 2000). In a rare study of the effect of incentives on public grants alone, incentives geared toward supporting researchers' explorative and creative behaviours were shown to "exert a profound influence on the subsequent development of breakthrough ideas", leading to remarkable growth in publication rates (Azoulay et al., 2011: 530). Such incentives are antithetical to the typically inflexible and "risk averse" funding models that can orientate research proposals toward "relatively safe avenues that build directly on previous results at the expense of truly explorative research" (Ibid: 531).

Whitley et al. suggest other ways that funders might influence research orientation and outcomes: "scientific communities [might use] reputational mechanisms" and "science policy and funding [...] expectations tied to resources" (2018: 113). Authorities can also impact how science innovation develops more generally because of their role in shaping and/or activating the environmental conditions that determine individual absorptive capacity; the "epistemic pluralism" needed for basic research and aberrant approaches (Ibid: 124); and "protected space": time and resources researchers have to explore the things they want to without threat to their reputation or career and/or intervention (Ibid: 112). While these factors are expressions of norms, they also reflect the environmental features that constitute the choice architecture of science innovation systems, (which are at times felt as a nudge). We argue that the typical choice architecture of most science innovation systems nudges researchers towards decisions in favour of the status quo, rather than the novel and the unknown, which orientates research and potentially its outcomes away from the realm of basic research.

Method and Context: How New Zealand Missions are Architecting for Change

New Zealand (NZ) is a useful context to examine the positive potential of behavioural science on the organisation and management of science innovation systems. This is because within its mission-led science activities, its government has recently outsourced the role of choice architect, one normally held by science advisors and policymakers, to the management teams of all eleven mission-led grand societal challenges that are currently being funded in NZ. These management teams have been given the prerogative to depart from the status quo in terms of the governance, management, administration and evaluation of science research to involve a broad-base of actors (including industry, Māori: the indigenous population, students and early career researchers), as well as to establish their own funding processes for the distribution of grants. This builds comparative cases in terms of policy and funding between the incumbent system, and mission-led, so called "National Science Challenges" (NSCs).

Here, however, we examine only the *Science for Technological Innovation* (SfTI) NSC. Within its community of over 300 researchers is a small social science team with the ability and the mandate to collect data related to the aforementioned aspects. The inclusion of this team in SfTI and its longitudinal nature is unprecedented in New Zealand. The "mission" of the SfTI NSC is to enhance NZ's capacity to use physical sciences and engineering for economic growth, and thus the remainder (and majority) of its participants are researchers in one of these two disciplines. SfTI aims to invest in basic research (or in this case, "stretch science") and multidisciplinary teams, to foster the best science most relevant (or "sticky") to NZ.

The social science team, *Building NZ's Innovation Capacity* (BNZIC), is one of the seven Spearhead (larger teams) that are funded in Phase 1 of SfTI, alongside 30+ smaller "high risk and reward" Seed projects. BNZIC obtained the data that informed this article among numerous others, through observation, interview, survey, and other documentary (minutes and email correspondence) methods. The longitudinal data has been collected from SfTI's inception in 2015, and at a regular interval since. This is projected to officially conclude in 2024. Having access to all SfTI-funded researchers adds to its comprehensiveness.

The data captures a trajectory of research orientation and outcomes, as well as internal and external impacts and engagements that have occurred, allowing us as part of BNZIC to better understand how the latter might influence the former. The data also probe the researcher experience within SfTI, in contrast to other funding approaches. This has been subsequently analysed using a grounded approach that extracts themes within/across research projects to identify which factors seem most closely connected to differing outcomes. Survey and other primary data augmented and provided a cross-check for these qualitative findings. Informed by these (and future) findings, the SfTI management team are in a position to design and enhance its choice architecture in an iterative and interactive process.

The expectation to deliver economic and/or societal benefit to the country, that is, 'impact', applies to all NSC research projects. At the same time, uncertainty and lags between sticky stretch science research and impact, are beginning to be recognised, yet still feature prominently in SfTI's key performance indicators (MBIE, 2015). Creating a choice architecture that encourages and engages stretch science research, while delivering on the impact imperative (with novel projects that can be commercialised), is the challenge of management teams. By applying a behavioural science lens to this challenge and the wider context so far discussed, we are able to offer an alternative interpretation of, and explanation as to how and why, aspects of both systems (new and old) might be helping or hindering the achievement of outcomes and impact.

The Case of Science for Technological Innovation: What We've Learnt so Far About Architecting for Impact

1. Friction costs and bounded rationality are growing problems for researchers that can exacerbate their status quo bias and orientate their research projects to the familiar

For some in the New Zealand science community, the impact imperative has instilled a "fear" of "government micro-managing research funding", when researchers are already "saddled with exorbitant levels of form filling, reporting and grant seeking" (Nicholls, 2017: 1, 6). Such friction costs, that is, elements of a process that may be minute, yet make something much more difficult (Service, 2014), are common in science innovation systems, coalescing mainly around review, approval and reporting (Van de Ven et al., 2017). Benner and Sandström argue that "existing institutional structures tend to hinder the evolution of new organisational routines" (2000: 301). We identify these friction costs as an obstruction to pro-stretch routines, and argue that they add an extra level of complexity and uncertainty for researchers whose "rationality [when making decisions about and during their research] is bounded because there are limits to our thinking capacity, available information, and time" (Simon, 1982 as cited by Samson, 2018: 124). How this potentially affects research orientation and outcomes emerges in the "satisficing" behaviour that tends to follow.

Satisficing is an heuristic that people fall back on when faced with bounded rationality. It supplants optimised decision-making with a "combination of sufficing and satisfying" (Samson, 2018: 147) and the selection of "options that meet…basic decision criteria" (Ibid: 147). Using heuristics to manage complexity (Tversky & Kahneman, 1974) can be problematic in the long run because "their use can also lead to systematic biases" (Thaler & Sunstein, 2008: 23). We observe this in the augmented status quo bias of researchers who pursue projects in which the science trajectory is known, or work has already progressed, instead of novel stretch science. We posit that operating in the context of the impact imperative, where funding expectations and friction costs are high, can shift researchers' primary decision-making criteria to delivering at least some more certain output(s), that is, it orientates their research to the familiar where the likelihood of some success is higher, and with less risks of the unknown, thus inadvertently leading to less stretch science.

Reducing friction costs is one way to address bounded rationality and mitigate some of the complexity that we argue disincentivises basic research. SfTI has approached this by introducing revised templates for submitting proposals that involve less time/effort to complete, encourage true novelty and stretch to be targeted, while still identifying key milestones and deliverables prior to funding that then form the basis for future reporting. Researchers have found these *"processes have been relatively light touch. We haven't been excessively hassled*"; they've been *"quite easy - just flowed naturally"*, in part because there is seen to be *"plenty of support"*. Comparatively, *"I think SfTI is doing much better than other funding agencies I have been* *working with"*. In terms of reporting, *"SfTI have a quick turnaround time on assessment and things like that"*; *"[w]hile they do have the yearly milestones, there's not a lot of reporting requirements. There's nothing that's too time-consuming"*. Another researcher *"remember[s] spending a lot more time on the [other funder's] yearly report"*, while others even find SfTI's *"monitoring much more engaging"* (Research Notes, 2019).

2. Funders' optimism bias may disincentivise researchers from pursuing basic research and stretch science

Exacerbating our first insight is funders' optimism bias about what funded researchers can achieve within a research project timeframe. This is symptomatic of the primary underlying issue we highlighted earlier, that is, choice architects of science innovation systems often do not perceive the complexities involved in the innovation process and consequently set expectations (such as rapid commercialisation) that are unrealistic within the parameters of a grant. Growing scarcity of public funding has contributed to increased competition between researchers (Whitley et al., 2018), who, in a bid to secure it, may avoid the unpredictability of pursuing riskier basic research in favour of the kinds of projects that are easier to connect to measures of impact.

Optimism bias is directed toward future events (Samson, 2019), and thus becomes especially relevant when an investment into a desired future event or outcome, like commercialisation, has been made. Researchers in the SfTI model did, at times, interpret their funders' behaviour as optimistically biased about the realities of the innovation process in NZ. *"If SfTI people expect us to have some sort of commercialisation after we finish this, which is in one year or two years, or three years, that is not realistic. If [this] is the case, then SfTI should not fund it"*. Similarly, another noted *"with this type of research, we can't have [an] immediate industry outcome at all, because - the reason is, we don't have industry support - and also the research is very much fundamental, which means it's far away from commercialisation - too far away"*. They understood the reason why SfTI has a focus on research impact. *"I can see why the NZ Government [giving the money] would want this to turn into commercialisation. But…the idea that you put some money into [X] in New Zealand, and that's going to develop commercial economic benefit for New Zealand, [that's] naïve…it's a worldwide eco-system…expecting New Zealand to build its own little eco-system is not going to work"* (Research Notes, 2019).

3. Large, multidisciplinary teams can be harnessed to socially norm desirable behaviour

Science missions aimed at addressing grand societal challenges need larger, diverse and multidisciplinary teams because the complexity of such challenges demands a multi-pronged approach. This requires actors to engage with different actors across the innovation ecosystem (Robinson & Mazzucato, 2018; Kuhlmann & Rip, 2018). Engaging with industry is often viewed as a discretionary exercise for academics (Tartari & Breschi, 2012), yet it can be an important part of making progress on grand societal challenges and generating impact. In the case of NZ, equally important is engaging with Māori and Māori organisations to "unlock the science and innovation potential of Māori knowledge, resources and people" (MBIE, 2019). Our evidence suggests that the SfTI management team's efforts to socially normalise these two types of engagement are working. This is a conclusion we have drawn from the fact that many Seed projects are proactively doing so, even though this is not a major criterion of their funding as it is for Spearheads. This appears in part due to the descriptive and injunctive normalisation of engagement likely socialised through regular interactions with SfTI management as well as Spearhead researchers at the Challenge's annual researcher workshop.

Here, again, are our interviewees speaking: *"The workshops in Auckland where...you're networking with other SfTI people - meeting some of the bigger [Spearhead] programs - you see how they've commercialised their products"*. Another researcher describes the impact that SfTI management had when they *"came and talked to us (before we'd even bid for any money) about Vision Mātauranga, about a Māori worldview, ...and that really struck me, because it sounds like just the most fantastic way to actually get a holistic view of what you're doing rather than how much money is this costing [or…] how much money we're going to get out of it"*. Similar views were echoed in that *"the [Māori] component is better integrated in SfTI than some of the other Science Challenges, I'd say, and some of the other funding processes"* (Research Notes, 2019).

4. Researchers can be nudged into greater pro-commercialisation behaviour using the messenger effect

Nudges can be built into choice architecture to change behaviour. Nudges are considered as such provided they do not stop people from doing other things or substantially alter any economic incentives, and remain relatively effortless (administratively and financially) to evade (Thaler & Sunstein, 2008). Given the policy focus on impact, SfTI have used nudges to get researchers to consider commercialisation of their stretch research.

They are generally nudged by theme leaders: members of the management team who act as technical and personal mentors to Seed and Spearhead project leaders. The inclusion of theme leaders as messengers and the depth of personalised interaction and feedback they afford, *"is very different from other funding agencies"*. Theme leaders were *"always offering contacts for commercialisation or anything like that"*, with most viewing this encouragement to connect to industry as being *"completely appropriate"*. These types of nudges influenced research orientation and outcomes in that, for some, *"every minute of the way, we're looking at the practical application"*.

A behavioural analysis would attribute the effectiveness of these nudges in part to their salience, given that they are delivered in such a highly personalised way. Humans are predisposed to observe what "we can understand [and] those things we can easily 'encode'…we are much more likely to be able to encode things that are presented in ways that relate directly to our personal experiences" (Dolan et al., 2010: 23). Theme leaders nudged researchers in their own environments, taking time to visit them personally in their offices and labs. A natural (and desirable) corollary of this is that relationships and "personal connections" started to develop. Researchers responded better to theme leader outreach because, for example, *"I know who these people are, so that's better than you just get an email from a name that you don't know"*.

A caveat, though, is that nudging for commercialisation to meet the expected outcomes of funders exhibiting optimism bias, could have the potential to reorientate stretch research projects and cap experimental learning. During a project, researchers potentially *"learn a lot of cool science things that are worth exploration that we could keep looking at, but of course we also want to end up with something that's eventually on the market, and that we can point to as something that's finally been commercialised"*. For some researchers, *"talking to industry"* has meant *"we've probably been pushed more to get things out and tested. Whereas otherwise, I probably would be spending more time in kind of the fundamental [to] understand science of what's going on, and more lab work"*. This was similar for another researcher who reorientated the project after initially *"thinking they [industry] would want something that was exceptionally better, but no, they were just happy to have a safer replacement"*. We would posit that these types of nudges have the potential to be counter-effective when they lead to behaviour that undermines the potential for broader longer-term impact embedded in stretch/basic research.

Implications and Limitations

This article fits in with a wider international trend of using behavioural science to improve and inform public policy. There are approximately 196 behavioural insights teams around the world dedicated to this very task. To date, their work has generally been consolidated in areas related to health, labour, energy, and the environment (Samson, 2018). For us, science and innovation policy was the natural next step, especially given that grand societal challenges are a new global policy priority (Kuhlmann & Rip, 2018; Else, 2018). Behavioural science offers significant value to any consideration of new and existing policy because with it comes a plethora of transferable and accessible tools, trials, case studies, methodologies, and insights (see Samson, 2018 & 2019; Dolan et al., 2010; Haynes et al., 2013).

What can other scholars learn from this? A greater appreciation of the covert and influential nature of choice architecture, and the potential that behavourial science has for providing new, thought-provoking interpretations of old problems. For practitioners, we hope to offer the beginnings of a behaviourally-based toolkit for science innovation policy, as it moves through a new era of government involvement and interest.

Our "findings" and implications are transferable to other countries and contexts from two perspectives. First, science innovation systems around the world are being acknowledged as more complex, suggesting the presence of friction costs and bounded rationality (Dowling, 2015; Pfotenhauer et al., 2016). Second, from the point of view that the contributions of behavioural science are predicated on the belief that "human judgement and decision making is mostly based on simple, fast and complexity-reducing heuristics that may lead to systematic biases", therefore assumptions about behaviour under certain conditions can be made (Emmerling, 2019: 40). However, responsible use of behavioural insights and interventions requires acknowledgement of the fact that behaviour is a product of the individual, their environment, and the interaction between the two, making behaviour highly contextualised at the micro level (Holzwarth, 2019; Emmerling, 2019).

Yet despite the rich theoretical and empirical foundation for our ideas, potential biases should be acknowledged, such as the problem of generalising from small samples (Tversky & Kahneman, 1982). Our study continues to grow in size (from 4 to eventually 10 Spearheads and close to 50 Seed projects), but given SfTI is actively seeking to shift behaviours, new interventions continue to be implemented, making it difficult to fully disentangle their impact from other actions. To counter these effects, our research methodology involves multi-party theory development and duplicate coding of data for cross-validation. Our data may have some limitations in terms of its representativeness though, given that the NSC's intentionally seek those with high capability, which may lead to a skewed set of behaviours.

Future research could go some way to mitigating some of these limitations through generating samples from other contexts both in New Zealand and internationally. In addition, future research could be directed toward developing a typology or index of policy and funding standards in use around the world, with a similar analysis (through a behavioural science lens) undertaken for each entry to determine how it might affect research orientation and outcomes. While such standards have been legitimised over time due to their benefits, they may now stand as an impediment to evolving "institutional orders" (Benner & Sandström, 2000, p.291), and calls for change at the macro level (Mazzucato, 2016; Robinson & Mazzucato, 2018; Kuhlmann & Rip, 2018), in the context of 21st century science innovation. Indeed, we would suggest that expecting change at a micro level without changes at the macro level is hopeful (and optimistic!) at best.

Conclusion

Identifying and understanding some of the choice architecture in science innovation systems that influences researchers' engagement with stretch or basic research has been the focus of this article. We have argued that this can be traced back, at least in part, to a knowledge gap between those creating the science and those creating the conditions for undertaking the science. The effect of such a gap is increased complexity for researchers operating within a choice architecture that seeks both stretch and impact from publicly-funded research, but does not address or accommodate the real constraints on researchers' ability to do so, namely the uncertainties, lags, and risks that are an inherent part of the science innovation process. Crucial influences on research orientation and outcomes in this context are government policies, like those for mission-led innovation, and the conditions, processes, and incentives attached to funding. Given the researcher concerns we have discussed, we would argue that the tried and true approaches to funding basic research will not be wholly effective when new policy initiatives are layered on to incumbent processes.

To determine influential factors more systematically, we have taken the approach of analysing this complex issue through a behavioural science lens, drawing on data from the *Science for Technological Innovation* National Science Challenge, one of New Zealand's eleven mission-led science projects. Given our unique position to observe and interact with the choice architects of this Challenge, we have identified a range of insights that can inform practice elsewhere, as well as when new policy initiatives emerge in NZ's future. These include how reducing the friction costs that are placed on researchers can address their bounded rationality and therefore potentially diminish their status quo bias; that funders need to recognise their optimism bias about achieving impact as it may create disincentives for researchers to pursue types of research in which the outcomes are less known; that desirable research orientations (such as those that combine different ontological and epistemological perspectives) and outcomes (like commercialisation) can be established or aspired to through social normalising; and finally, that nudging can also be used to orientate research toward commercialisable outcomes, which is especially effective when made more salient through personalisation. These findings are offered as the beginning of a behaviourally-based toolkit for science innovation systems to develop a choice architecture that more effectively fosters research with multiple and potentially conflicting objectives, such as basic/stretch research that nevertheless delivers impact.

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Giving Science Innovation Systems a 'Nudge'

Kirsty de Jong, Urs Daellenbach, Sally Davenport, Jarrod Haar and Shirley Leitch

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Kirsty de Jong is an early career researcher in the Science for Technological Innovation National Science Challenge based out of the Victoria Business School, at the Victoria Univeristy of Wellington, New Zealand. Her research focuses on the behavioural aspects of the 30+ "high risk and reward" Seed projects and the larger Rangatahi (youth-led) Spearhead project involved in the Challenge. Prior to joining the Challenge, Kirsty was with The Behavioural Insights Team - a social purpose research company who advise on, and redesign public services using behavioural science. She has a Master's in Museum and Heritage Practice from Victoria University of Wellington.

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