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Compatibility effects in the prescriptive application of psychological heuristics: Inhibition, Integration and Selection

by

Shashwat M. Pande[a,b*], K. Nadia Papamichail[a,c] and Peter Kawalek[b]

[a]Alliance Manchester Business School, The University of Manchester, United Kingdom

[b]School of Business and Economics, Loughborough University, United Kingdom

[c]The Alan Turing Institute, British Library, United Kingdom

[*]Corresponding Author, email: s.m.pande@lboro.ac.uk

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Abstract:

Recent studies have proposed the use of "fast and frugal" strategies as viable alternatives to support decision-processes in cases where time or other operational constraints preclude the application of standard decision-analytic methods. While a growing body of evidence shows that such procedures can be highly accurate, limited research has evaluated how well decision-makers can execute the prescriptive recommendations of aids based on such strategies in practice. Drawing on the behavioural, neuropsychological and decision-analytic literatures, we propose that an alignment between individual, model and task features will influence the effectiveness with which decision-makers can execute strategies that draw on prescriptive psychological heuristics – "fast and frugal" or otherwise. Our findings suggest that strategy execution is highly sensitive to task characteristics however, the effects of the number of alternatives and attributes on individuals' ability to deploy a given strategy, differ in magnitude and direction depending on which decision-strategy is prescribed. A more compensatory decision-style positively affected overall task performance. Subjects' ability to regulate inhibitory control was found to positively affect non-compensatory strategy execution, while having no discernible bearing on comparable compensatory tasks. Our findings reinforce that rather than an aspect of the prescriptive model, synergies between individual, model and task features are more instrumental in driving task performance in aided MCDM contexts. We discuss these findings in light of calls from OR scholars for the development of decision-aids that draw on prescriptive "fast and frugal" principles.

Keywords: Behavioural OR; Psychological heuristics; Compatibility effects; Multiple-criteria decision analysis; Executive function

1. Introduction

One of the central findings from behavioural decision-research over the past two decades suggests that decision-makers often shift to "fast and frugal" choice-heuristics depending on task-contingencies (Gigerenzer, Todd, & ABC Research Group, 1999; Payne, Bettman, & Johnson, 1993). This framework proposes that rather than integrating all available information in the resolution of a decision-problem, decision-makers are highly selective in what pieces of discriminatory information they attend to and what they ignore. For instance, while a normatively held decision-theoretic model such as the weighted additive difference rule (WADD, Keeney & Raiffa, 1993) assumes that decision-makers assign weights to each attribute and compute the product sums for each available alternative until arriving at a final choice, lexicographic models suggest that in arriving at a decision, individuals may only attend to a single(subset) of highly salient attribute(s), ignoring all other problem information within the choice-domain (e.g. Fishburn, 1974; Gigerenzer, Hoffrage, & Kleinbölting, 1991; Tversky, 1969). As a result, these latter classes of models, said to comprise the mind's "adaptive toolbox" are frugal – in that they dispense with the notion of optimization and often even probabilities and utility computations – and therefore are assumed to be faster as decisions can be based on highly intuitive search, stopping and decision-rules (Gigerenzer & Selten, 2001). Even though the applicability of such approaches to general decision-making contexts remains highly contested (e.g. Bröder & Newell, 2008; Hilbig, 2010), the "fast and frugal" framework provides three basic insights into unaided decision-processes. 1) Decision-makers are parsimonious in their expenditure of scarce cognitive resources, 2) The decision-strategy applied depends on the task in question, and 3) Decisions are often based on the relative salience rather than the integration of all information within the task-domain. These strategies are therefore termed *non-compensatory*, as they do not involve adjustments for explicit trade-offs between alternative and attribute values – i.e. high values on one criterion do not compensate for low values on others – as would be the case under most expectation-based decision-theoretic frameworks. Instead, the "fast and frugal" framework takes a more boundedly-rational position on human decision-processes and suggests that individuals often formulate aspirational thresholds (e.g. satisfice, Simon, 1955) or a hierarchical ordering of attributes (e.g. eliminations by aspects, Tversky, 1972) in order to reduce the amount of cognitive effort that needs to be expended on the resolution of a decision-problem. Non-compensatory strategies are thus, often conceptualised as an adaptive behavioural response to increasing complexity within a decision-environment.

At the same time, as these strategies involve relaxing some of the central psychological assumptions of Expected Utility Theory (EUT) (see for instance, Katsikopoulos & Gigerenzer, 2008) and rely on a less-complete processing of available information across alternative and criterion values, they have traditionally been assumed to be more error-prone and susceptible to decreases in choice performance as compared to more compensatory selection procedures (Beach & Mitchell, 1978; Payne et al., 1993; von Winterfeldt & Edwards, 1986). An important contribution of Gigerenzer et al.'s (1999) research programme however, was to draw attention to the fact that in a number of circumstances, simple non-compensatory heuristics could perform comparably – and in some cases, even outperform – more complex and computationally expensive compensatory selection rules. This basic insight has since found support in analytical, simulation and behavioural contexts (for reviews from an OR perspective see, Katsikopoulos, 2011; Katsikopoulos, Durbach and Stewart, 2018; Martignon and Hoffrage, 2002). Indeed, recent results highlight that not only can non-compensatory approaches towards modelling choice, lead to the reconciliation of various behavioural violations of EUT, they also satisfy a number of standard decision-theoretic axioms (Katsikopoulos & Gigerenzer, 2008).

While the core insights from the "fast and frugal" research programme have been applied in OR contexts such as classification and forecasting, the decision-analytic literature has mainly focussed on the applicability of simple heuristic-based methods for multi-attribute choice problems characterised by binary-attributes (Baucells & Carrasco, 2006; Hogarth and Karelaia; 2005; Katsikopoulos, 2013). Furthermore, while research in the psychological literature has highlighted the primacy of heuristic decision-making in descriptive multiple-criteria decision-making (MCDM) settings both, in laboratory (e.g. Bröder, 2000; Bröder & Schiffer, 2003) and naturalistic environments (Ford et al., 1989), very few studies have explicitly focussed on the antecedents of prescriptive strategy use. This latter aspect remains contested within the behavioural decision-making community with some suggesting that simple non-compensatory strategies may not be particularly effortless to execute as a result of the extensive amount of pre-computation involved in establishing a prescriptive hierarchy of preferences (e.g. how hierarchies for discriminatory information and stopping-rules are established in the first place, Juslin & Persson, 2002; Marttunen et al., 2019). Similarly, there is growing evidence to suggest that compensatory strategies may not be as difficult to apply to a decision-problem if the decision-maker is familiarised with the underlying intuition behind the model. Experimental investigations for instance, have highlighted that while decision-makers may not necessarily assign weightings to decision-attributes, simpler compensatory procedures such as an equal-weights strategy or frequency-based heuristics are fairly prevalent in practice and often approximate the variance in choice data (Alba & Marmorstein, 1987; Glöckner & Herbold, 2011; Pachur & Forrer, 2013).

With the recent resurgence of interest in behavioural OR (B-OR), a number of researchers have suggested the development and application of decision-aids based on non-compensatory principles (Fasolo, McClelland and Todd, 2007; Katsikopoulos & Fasolo, 2006; Keller & Katsikopoulos, 2016; Kottemann & Davis, 1991; Vansnick, 1986). As a result, the adeptness with which individuals can execute these strategies becomes an important area that needs to be investigated in a systematic manner within the OR community. Indeed, one of the principle objectives of B-OR is to investigate how individual and task features influence model use amongst decision-makers (Franco & Hamalainen, 2015; Katsikopoulos, 2016; O'Keefe, 2016). While the circumstances in which individuals self-select or switch decision-strategies is an important open question in both behavioural decision-theory and OR, the question of how well individuals can execute indicative strategies is of much greater importance in contexts where model-based interventions may be appropriate.

In this study, we therefore direct our efforts towards interrogating the differences between simple compensatory and non-compensatory psychological heuristics from the perspective of prescriptive strategy execution. We conduct an experimental investigation in order to evaluate how task complexity and individual characteristics influence performance in a hypothetical MCDM task. Drawing on the behavioural, psychological and decision-analytic literatures, we derive a set of compatibility hypotheses that suggest synergies between individual, model and task characteristics may play a role in facilitating strategy execution. Our findings highlight four core features relating to aided strategy execution in MCDM contexts: 1) The differences in the performance of compensatory and non-compensatory heuristics can be fully explained as a function of task characteristics. 2) The effects of the number of alternatives and attributes on individuals' ability to deploy a given strategy, differ in magnitude and direction depending on whether the prescribed strategy is compensatory or non-compensatory. 3) While a stated preference towards more compensatory decision-making affects overall task performance, this tendency does not provide much discriminatory insight relating to actual strategy execution. 4) The adeptness with which individuals can regulate selective attention and inhibit non-instrumental information improves task performance in non-compensatory contexts while having no bearing on comparable compensatory tasks.

We position these findings within the context of the broader B-OR literatures and discuss their relevance in informing the design of decision-aids and support tools that draw on non-compensatory principles. In the following sections, we review previous work on decision-strategies, particularly highlighting the gaps in the extant literature relating to prescriptive strategy execution. Subsequently, we present our theoretical framework and hypotheses before culminating with sections presenting the analysis and discussion of our main results.

2. Previous Research

2.1 From Descriptive to Prescriptive Approaches to Non-Compensatory Decision-Making

In the preceding section, we indicated that despite the wide-spread discussions on strategy shifting and adaptive strategy selection in the behavioural and psychological literatures, the issue of strategy execution has received comparatively less attention. An important reason for this is that traditionally, decision-research has held the view of non-compensatory strategy use as inferior and suboptimal deviations from normative decision-making, a tendency which decision-analysts could alleviate by supporting decision-makers with tools and procedures to encourage the adoption of expectation-based decision-theoretic frameworks (Keeney & Raiffa, 1993; von Winterfeldt & Edwards, 1986). In their seminal paper on strategy selection, Beach and Mitchell (1978) echo this sentiment and propose an intuitive argument suggesting that the selection of a decision-strategy is often contingent on the demands of a task and a trade-off between the accuracy and effort required in arriving at a final course of action. They classify strategies as "aided-analytic or unaided-analytic" and "non-analytic", referring to compensatory and non-compensatory decision-making respectively. Despite their view that what is 'optimal' in a given decision-context depends on the specific requirements of the task, Beach and Mitchell's (1978) contingency model takes a rather pessimistic position on non-compensatory strategy use, suggesting that such strategies may disproportionately lead to erroneous judgements.

As is now well known, this latter assertion does not necessarily seem to be the case and in a number of circumstances – particularly when information acquisition costs are high (Bröder, 2000), decisions are made under extreme time pressures (Payne et al., 1993; Rieskamp & Hoffrage, 1999) or, when criterion information is obfuscated and must be retrieved from memory (Bröder & Schiffer, 2006) – non-compensatory heuristics can lead to decisions that converge towards choices predicted by more complex weighted linear-additive models. While early behavioural decision-research in the vein of Tversky and Kahneman's (1974) heuristics and biases programme refrained from providing a formal prescriptive basis for strategies that deviated from other expectancy-based models, decision-theorists have increasingly turned their focus towards formalising these aspects of behaviour, either as mathematical models (e.g. eliminations by aspects, Tversky, 1972; satisficing, Simon, 1955) or as a set of explicit verbal protocols following a sequential series of instructions (e.g., frequency of good and bad dimensions, Alba & Marmorstein, 1987; majority of confirming dimensions, Russo & Dosher, 1983). Indeed, this distinction is a core point of departure between the “fast and frugal” framework proposed by Gigerenzer et al. (1999), the standard decision-analytic approach (Keeney & Raiffa, 1993) and the heuristics and biases program (Tversky & Kahneman, 1974).

Instead of viewing strategies that rely on the maximisation of expected utility by integrating all relevant problem information as the normative ideal, Gigerenzer and Todd (1999) suggest that in many cases formal non-compensatory procedures can be viewed not just as descriptions of human behaviour but as a prescriptive basis for guiding action if certain task requirements are satisfied. While there is still a lack of consensus regarding the precise conditions under which non-compensatory models may be applied as prescriptive decision-aids – French, Maule, and Papamichail (2009) for instance, note that there is insufficient evidence that such procedures are useful for complex tactical and strategic problems where decision-makers may not have a good understanding of their environment – proponents of the “fast and frugal” view have cited the simplicity and transparency associated with non-compensatory strategies as salient benefits to their applicability to a range of decision-problems and in particular, highlighted the usefulness of such methods in reconciling the complexity of decision-analytic interventions with the psychological insights derived from the past four decades of research in behavioural decision-theory (Morton & Fasolo, 2009). Indeed, simple non-compensatory decision-aids have been successfully applied in contexts ranging from healthcare and medicine, to the legal profession and business and consumer contexts (e.g. Gigerenzer & Gaissmaier, 2011) and a growing body of research within decision-analysis has highlighted why such heuristics – that often (but not always, e.g., Katsikopoulos et al., 2020) rely on binary comparisons of attributes against a given criterion – perform well in situations characterised by uncertainty (Gigerenzer, Hertwig and Pachur, 2011; Katsikopoulos, 2013). Keller and Katsikopoulos (2016) for instance, provide an overview of circumstances when non-compensatory decision-aids might be appropriate in operational decision-making and illustrate an application of a lexicographic procedure in the context of military decisions made by ground troops. Similarly, Katsikopoulos, Durbach and Stewart (2018) integrate the behavioural, psychological and OR literatures and propose a decision-aid to evaluate when simple decision-models might be appropriate for a particular decision-context. At the same time, while non-compensatory strategies may better correspond with decision-makers intuitions and approximate the performance of optimising models, the assertion that they are necessarily simpler to execute as compared to more compensatory approaches seems to rest on the belief that the latter set of models "assume the human mind has essentially unlimited demonic or supernatural reasoning power (Gigerenzer & Todd, 1999, pp. 7)"– a contention that must be sufficiently qualified in the context of operational decisions.

2.2 Simple or Non-Compensatory?

An important point to note at this juncture is that just because a strategy is compensatory does not imply that it is also complicated to apply. Indeed, in contrast to the view that compensatory decision-models assume unbounded rationality on the part of the decision-maker, the limits of optimization are not only well known (Ackoff, 1979; Simon, 1955), but one of the principle arguments supporting the use of soft OR techniques in conjunction with optimization methods in decision-analysis (Franco & Montibeller, 2010; Mingers, 2011). To a large extent, this insight has prompted the development of special cases of the WADD framework and resulted in the proposal of a number of simpler heuristics that are compensatory – i.e. still depend on the integration of all available task information – but relatively more accommodating of a decision-maker's limited cognitive resources. For instance, while a compensatory strategy that ignores attribute weights (e.g. equal weighted rule, Einhorn & Hogarth, 1975) is relatively trivial to execute compared to a weighted additive difference strategy, by the same token, non-compensatory strategies like eliminations by aspects that assume decision-makers can construct a probabilistic ranking of attributes, attend to only those attributes and inhibit all other problem information can be far more involved than simpler one-reason-based decision-rules (Goldstein & Gigerenzer, 2002). This latter point is particularly relevant when decision-aid's that draw on prescriptive "fast and frugal" principles place requirements on decision-makers' abilities to apply such strategies in an error-free manner – often assuming that individuals can execute such approaches with perfect attention and recognition memory.

In their systematic study of a number of decision-strategies, Bettman, Johnson and Payne (1990) attempted to develop a measure for decision-effort based on the basic cognitive operations that need to be applied in order to execute a particular strategy. They count what they term "elementary information processes (EIPs)" – e.g. products, additions, eliminations etc. – that a particular strategy calls for and suggest that the difficulty in executing any given strategy is the weighted sum of these procedures. For instance, they suggest that since computing the product for attribute values against decision-weights is more effortful than summing un-weighted attribute values across alternatives, the former consideration should play a larger role in informing which strategy is executed as the complexity of the task increases. In many respects, Bettman et al.'s (1990) view on contingent strategy selection is similar to the model proposed by Beach and Mitchell (1978), however as a result it suffers from its limitations as well. Most importantly, while Bettman et al. (1990) convincingly demonstrate that the number of EIPs involved in executing a particular strategy affects the time and self-reported decision-effort in preferential choice problems, their results highlight large individual differences with respect to the consistency with which decision-makers apply prescribed decision-strategies as well as their sensitivity to task characteristics. A fairly obvious consideration in implementing a prescriptive decision-aid, particularly where the goal is to simplify strategy execution, is that the prescribed selection-rule should be applied by a decision-maker in a manner that is consistent with the decision-aid's recommendations. Indeed, this consistency argument is one of the prominent reasons that decision-analysts have traditionally focused their efforts on refining compensatory decision-making procedures as these are often assumed to be more robust to differences in individuals' decision-styles, information-processing preferences and personal characteristics (von Winterfeldt & Edwards, 1986). If as some have suggested, B-OR research is to serve as a bridge between soft and hard OR (Keller & Katsikopoulos, 2016; Morton & Fasolo, 2009), it is precisely these latter aspects of strategy execution that require systematic evaluation, particularly with respect to how such characteristics interact with task features in determining the effectiveness with which a particular decision-strategy can be employed towards the resolution of a decision-problem.

2.3 Task Environments

In line with the view that individuals are equipped with a 'toolbox' of a diverse range of strategies, research has attempted to evaluate the conditions under which decision-makers might adopt simpler non-compensatory approaches to contend with increasing complexity in task environments. Early work building on Payne et al.'s (1993) "effort-accuracy framework" suggested that, rather than being a property of the difficulty associated with executing a particular decision-rule, complexity should instead be conceptualised as a feature of the task in question. The information overload paradigm for instance, has long held that as the number of alternatives and criteria actively considered over the course of making a decision are increased, choice quality can become adversely affected as a result of individual cognitive and motivational limitations (Iyengar & Lepper, 2000; Jacoby, Speller, & Kohn, 1974). While the initial results from Jacoby et al. (1974) and Iyengar & Lepper (2000) have been heavily criticised on both theoretical and methodological grounds (e.g. Russo, 1974; Scheibehenne, Greifeneder, & Todd, 2010 for a meta-analytic study), there appears to be an emerging consensus that information overload is both a plausible and relevant phenomenon in MCDM problems, even if the precise conditions under which this becomes observable remain contested (Jacoby, 1984; Korhonen et al., 2018; Malhotra, 1984; Scheibehenne et al., 2010). Payne et al. (1993) appeal to precisely this logic in suggesting that as the number of alternatives and criteria under consideration increase, decision-makers are more likely to make errors as a result of their need to apply non-compensatory decision-rules in order to reduce the processing requirements associated with compensatory procedures. Both Jacoby et al. (1974) and Payne et al. (1993) however, assess errors in terms of a choice being consistent with the predictions of benchmark models such as the WADD rule, an assumption that may not be appropriate in a number of situations (e.g. see for instance Malhotra, 1982).

Indeed, in addition to strong behavioural evidence in favour of the prevalence of non-compensatory decision-making, a growing body of literature has emerged to highlight that rather than instances of irrationality, non-compensatory strategies can in many cases be highly effective and accurate in determining an optimal course of action. Hogarth and Karelaia (2005) for instance, compare the performance of deterministic eliminations by aspects models (DEBA) and other compensatory strategies in single-criterion multi-attribute choice problems and demonstrate that non-compensatory selection procedures out-perform models that explicitly confront trade-offs between alternative and attribute values. These findings were subsequently organised in a mathematical theory presented in Katsikopoulos (2013). Along with the early studies documenting the surprising accuracy of simple non-compensatory decision-strategies (e.g. Borges et al., 1999; Gigerenzer & Goldstein, 1996), there is now a considerable body of evidence converging around the finding that simple heuristics can lead to effective decision-making and in some cases, even optimal choices (Baucells & Carrasco, 2006; Brighton, 2006; Hogarth & Karelaia, 2006; Karelaia, 2006; Katsikopoulos & Martignon, 2006). Simplicity, coupled with the surprisingly effective performance of non-compensatory heuristics, suggests that drawing on the prescriptive foundations of these strategies can be an appealing prospect for decision-analysts (see for instance, Katsikopoulos, 2011; Katsikopoulos, Durbach and Stewart, 2018; Martignon and Hoffrage, 2002), particularly in contexts where time pressures or an abundance of information preclude the systematic integration of all relevant criteria within the task domain. At the same time, due to the sensitivity of such decision-rules to seemingly minor changes in task environments and individual characteristics, investigating the conditions where individuals can apply these strategies more effectively becomes a pressing concern in evaluating their performance as prescriptive decision-aids.

2.4 Executive Function and Capacity Constraints

A number of researchers have attempted to study the individual sources of variation in the selection and use of different decision-strategies. Traditionally, this strain of research investigated the role of higher order cognitive functions such as fluid intelligence, working memory capacity and task interference as possible determinants of adaptive strategy use. Payne et al. (1993) conceptualised a tentative explanation to contend with the individual differences in adaptive strategy use in their experiments, suggesting that strategy shifting may be associated with differences in individuals information processing abilities – specifically, they suggested that as the complexity of the task environment increases, decision-makers with lower cognitive capacity should be more likely to employ simpler non-compensatory selection procedures. Bröder and Eichler (c.f. Bröder & Newell, 2008) attempted to test this hypothesis in an experimental task and to surprising effect, discovered that individuals that were more intelligent tended to favour non-compensatory strategies if the task environment supported their use – a finding that was replicated in additional studies (Bröder, 2003). In other experiments, when an exogenous cognitive load was placed on participants – subjects were asked to retain a running count of the occurrence of the number nine in memory while performing a behavioural task – Bröder and Schiffer (2006) demonstrated that rather than shifting to non-compensatory strategies as a function of higher cognitive load, subjects were *more* likely to apply compensatory selection procedures in the high cognitive load condition.

These findings suggest that the difficulty associated with the execution of compensatory strategies may have initially been overstated – indeed, task interference and added cognitive load seemed to restrict non-compensatory decision-making rather than facilitate it. Bröder and Newell (2008) interpret these results as suggestive of the fact that rather than strategy execution, cognitive capacity is more instrumental in the meta-cognitive judgement responsible for determining which strategy is appropriate for a particular task environment. This observation also speaks to experimental results that suggest over time, experts formulate simple rules-of-thumb to inform their decision-making and are more likely to evaluate options using non-compensatory processes as compared to novices (Shanteau, 1992; Garcia-Retamero and Dhami, 2009).

In contexts where decision-aids draw on prescriptive "fast and frugal" principles, the question of whether a particular environment is conducive to non-compensatory processing is often determined by the analyst in conjunction with various stakeholders (e.g. Keller & Katsikopoulos, 2016), as a result this means that the effectiveness of such interventions depends not only whether a particular task environment supports the use of such strategies, but also the adeptness with which individuals can execute the recommendations of the decision-aid in practice – an area that still remains largely under researched.

2.5 Cognitive Styles

A related but conceptually distinct approach towards evaluating the role of individual differences in strategy execution draws on psychometric and trait-based notions, appealing to presumably stable individual orientations in explaining decision-making outcomes. A number of studies have demonstrated the relevance of stable personality traits in general decision-making contexts (Pacini & Epstein, 1999; Schwartz et al., 2002; Weber & Milliman, 1997), however the extent to which these characteristics are applicable to aided decision-making remains unclear. Bröder (2012) summarises a number of experiments attempting to establish the individual determinants of adaptive decision-making based on a broad range of decision-maker characteristics – e.g. impulsivity, need for cognition, action orientation along with the "Big Five" personality traits, often considered to be fundamental personality dimensions – however their results remained inconclusive and did not indicate any discernible influence of such characteristics in either strategy selection or execution. In an early observational study, Zakay (1990) conceptualised the reliance on a particular decision-strategy as an individual preference to use either a predominantly compensatory or non-compensatory decision-style. In contrast to Bröder (2012), Zakay's (1990) approach was more granular in that their instrument was conceptualised as a specific bi-polar construct measuring subjects self-reported reliance on primarily compensatory (or non-compensatory) decision-making. Their initial results suggested a correlation between subjective decision-styles and actual strategy use on a subsequent decision-making task. Shiloh, Koren and Zakay, (2001) extended these findings and demonstrated that a basic orientation towards compensatory decision-making may influence subjective assessments of decision-complexity and conclude by calling for a systematic investigation of the "basic tendencies" that may affect adaptive strategy use.

Both these studies however do not cast any light on whether such decision-styles have any qualitative impact on decision-making – indeed, while they demonstrate that self-reported decision-styles may correspond to strategy use, the assertion that individuals apply these strategies with any consistency or accuracy does not follow from these findings. In cases where model use has been considered in other OR contexts – for instance in the use of visualisations and information displays – individual differences have been consistently reported however, personality correlates are for the most part, weakly – if at all – related to task performance (O'Keefe, 2016).

3. The Compatibility Hypothesis

As the support for the effectiveness and precision of non-compensatory strategies suggests, far from being instances of irrational decision-making, these strategies can be particularly well suited to a number of task environments. Calls from OR scholars for decision-aids and support tools drawing on these principles reinforces the success of the "fast and frugal" framework not just as a description of behaviour but a potentially vast source for decision-analysts to draw on, in supporting individual decision-processes. At the same time, the complex assemblages of individual and environmental features means that it can often be difficult and perhaps, inappropriate to study these issues in isolation from one another. These considerations, coupled with the lack of a systematic analysis of the interactions between individual, model and task characteristics investigating aided strategy execution in MCDM contexts, led to the conception of our *compatibility hypotheses*.

Broadly stated, the compatibility hypothesis suggests that an alignment between the inputs and outputs within a decision-context influences the quality of decision-outcomes. The notion that synergies between individual and environmental features can play a role in facilitating good decision-making has been evaluated in the behavioural literature ever since the seminal work of Herbert Simon (1955, 1971, 1990), with his proposition that effective decision-making arises from the alignment between the limited cognitive resources that decision-makers can access and the complexity of the environment within which they intend to act. This hypothesis has since been applied to a range of problems investigating compatibility between broad stimulus and response characteristics (Kornblum, Hasbroucq, & Osman, 1990), decision-styles and situational factors (Ayal, Rusou, Zakay, & Hochman, 2015), as well as state-variables and task-requirements (Kruglanski & Gigerenzer, 2011). While Simon's work has been influential in all areas of the behavioural sciences, particularly the literatures in behavioural economics (e.g. Mallard, 2015), design psychology (e.g. Hatchuel, 2001) and situation awareness (e.g. Flach, Mulder, & Paassen, 2004), the hypothesis was brought to bear on decision-analytic settings, by Slovic, Griffin and Tversky (1990), to explain why normatively equivalent methods of elicitation could sometimes give rise to systematically different responses.

In aided MCDM contexts, compatibility effects may manifest as a result of synergies between decision-maker characteristics and the features of the decision-model in question, as well as those between the model and task environment. We conceptualise three such sources: 1) the compatibility between the prescribed decision-strategy and the complexity of the decision-environment, 2) the compatibility between individuals' preferred decision-style and the prescribed decision-strategy, and 3) the compatibility between decision-makers' ability to inhibit non-instrumental information and the prescribed decision-strategy. We draw on these aspects to address two simple research questions contrasting between compensatory and non-compensatory strategy execution in aided MCDM contexts.

1) Does the complexity of a decision-task, indexed by the number of alternatives and criteria under consideration, affect the accuracy with which individuals can execute prescribed decision-strategies?
2) Do individual characteristics affect the accuracy with which decision-makers can execute prescribed decision-strategies over and above the effects of task features?

3.1 Decision-Model and Task Complexity

As we discussed in the previous sections, the work of Payne et al. (1993) has demonstrated that as the complexity of a decision-environment increases, decision-making behaviour is more compatible with non-compensatory strategy execution. While Payne et al. (1993) initially conceptualised such strategies as being inferior to more compensatory decision-models, there is ample evidence suggesting their suitability in a number of circumstances. The most salient to our approach is Fasolo, McClelland and Todd's (2007) suggestion that in cases where criterion weights are unequally distributed, non-compensatory procedures can lead to decisions that are consistent with decision-makers' "true" preferences. This is a rather intuitive argument as it speaks to one of the core distinctions between compensatory and non-compensatory strategies. More precisely, while compensatory decision-models take into account all attributes for all alternatives – for instance, less important attributes may be represented by lower criterion weights but are still taken into consideration – non-compensatory decision-rules simply disregard non-instrumental features, basing the ultimate course of action on only the most salient attribute(s). This means that compensatory decision-models become objectively more difficult to execute as more criteria are added to a choice problem, regardless of their relative importance. As a result, we argue that in cases where underlying preferences remain unaffected by the inclusion of additional criteria, prescribed non-compensatory decision-strategies will be less susceptible to decreases in choice performance than comparable compensatory strategies as the number of criteria increase.

Similarly, the role of the number of alternatives in a choice set can have implications on the quality of choices made by decision-makers. This aspect has been extensively studied within the psychological and marketing literatures under the banner of information or choice overload (Iyengar & Lepper, 2000; Jacoby et al., 1974; Malhotra, 1984). It is fairly obvious that increasing the number of alternatives that a decision-maker must actively consider in determining a suitable course of action will increase the search space within the problem context. At the same time the extent to which this affects individuals' ability to execute simplifying strategies remains largely contested (Russo, 1974). Gigerenzer and Todd (1999) suggest that non-compensatory strategies can be effective information handling tools for situations where decisions are characterised by an abundance of information, however they do not explicitly disentangle the role of attributes and alternatives. This may be a problematic omission as the number of alternatives and criteria can affect choice quality in distinct and seemingly unrelated ways (e.g. Malhotra, 1984). At the same time, based on arguments from Payne et al. (1993) as well as Gigerenzer et al. (1999) that non-compensatory strategies are universally less involved and can be executed with relative ease, we formulate the expectation that as the number of alternatives increases, prescribed non-compensatory strategies will be less susceptible to decreases in performance as compared to compensatory strategies.

Hypothesis 1(a): Prescribed non-compensatory (compensatory) strategies will be less (more) susceptible to decreases in choice accuracy as the number of decision-criteria increase.

Hypothesis 1(b): Prescribed non-compensatory (compensatory) strategies will be less (more) susceptible to decreases in choice accuracy as the number of alternatives increase.

3.2 Decision-Style and Decision-Model

Another important aspect that may influence task performance is the compatibility between individual traits and the requirements of the task at hand. McMackin and Slovic (2000) for instance, demonstrated compatibility effects between a deliberative mode of thought and deliberative judgements. Their main results suggested that while deliberation improved performance on a task explicitly calling for analytical processing – i.e. subjects were asked to make numerical estimations – a deliberative mode of thought degraded performance on a task that required affect-based judgements. In a similar investigation based on a measure for rational or experiential information processing styles (see for example, Pacini & Epstein, 1999), Ayal et al. (2015) demonstrated that individuals with an intuitive style performed better on an intuitive task – demonstrating fewer intransitive preferences – whereas those with a more analytical style performed better on an analytical task. While Gigerenzer and Todd (1999) propose that the selection of a strategy can be inferred solely from the structure of the decision-environment, others have argued for the importance of basic individual dispositions in determining the effectiveness with which these can be executed. Zakay (1990) for instance, conceptualises a preference for a predominantly compensatory or non-compensatory decision-strategy as a relatively stable individual characteristic, arguing that a basic tendency towards a particular decision-style may have implications for which strategies an individual employs in practice (Shiloh et al., 2001). If this is indeed the case, then it should be possible to observe similar compatibility effects between decision-style and strategy execution as reported in other studies (Ayal et al., 2015; McMackin & Slovic, 2000). In other words, a more compensatory decision-style should correspond to relatively better performance on tasks calling for the execution of compensatory strategies as compared to those calling for non-compensatory strategies.

Hypothesis 2: A higher subjective preference for a compensatory decision-style will be positively related to individuals' abilities to execute prescribed compensatory strategies.

3.3 Inhibitory Control and Decision-Model

The relationship between cognitive ability and the ease with which decision-makers can apply various decision-rules has been of interest ever since the early work of Beach and Mitchell (1978). At the same time, while the relationships between executive function and adaptive strategy use have been widely hypothesised (e.g. Payne et al., 1993; Simon, 1971), they have rarely been the subject of empirical examination. Traditionally, these aspects have been studied under the premise of broad capacity constraints, and their specific components – attentional shifting, inhibitory control and working memory capacity – have often been treated synonymously in the rare studies that have attempted to investigate their role in adaptive strategy selection (Bröder, 2003). More recently, primarily in the neuropsychological literature, research has attempted to identify and disentangle the precise cognitive determinants of strategy execution. Del Missier, Mäntylä and Bruine de Bruin (2010) – in what to our knowledge is the first study considering the role of executive functions on strategy execution – examined the relationship of working memory capacity, inhibition and attentional shifting on downstream measures of decision-maker competency. Their results suggested that while attentional shifting was associated with stable risk perceptions, inhibitory attentional control was positively related to individuals' abilities to accurately apply a variety of decision-rules (see also, Del Missier et al., 2012; Rosi et al., 2019). In interpreting this latter finding, Del Missier et al. (2010) suggest that "the successful application of decision-rules requires the capacity to selectively focus attention and inhibit irrelevant (or no more relevant) stimuli (pp. 69)." While they do not distinguish between compensatory and non-compensatory strategy execution, the substance of their conclusions seem to cohere to the fundamental conception of non-compensatory decision-rules as highly selective when contrasted against more integrative compensatory procedures. In simpler terms, inhibitory attentional control is the ability of individuals to regulate what they pay attention to and what they ignore. Thus, it is often conceptualised as the component of the greater attentional system responsible for *goal-directed* and *selective* attentional processes (for an overview see Diamond, 2013). When extending this to the domain of prescribed strategy execution, while both compensatory and non-compensatory strategies are goal-directed in nature, only the latter are highly selective. As a result, we argue that highly selective, non-compensatory strategies should be more compatible with individuals' abilities to exercise inhibitory control. Based on this line of reasoning, we expect that higher inhibitory control will correspond with relatively better performance on tasks calling for the execution of non-compensatory strategies as compared to those calling for compensatory strategies.

Hypothesis 3: Better inhibitory control will be positively related to individuals' abilities to execute prescribed non-compensatory strategies.

Table 1. Hypothesised relationships of task and individual variables on the strategy execution process contrasted between compensatory and non-compensatory decision-strategies.

	Compensatory	Non-Compensatory	Overall
Task Level			
No. of Alternatives	– – –	(–)	– –
No. of Attributes	– –	(–)	–
Individual Level			
Decision Style[a]	(+)	NH	NH
Inhibitory Control[b]	NH	(+)	+

Note. The negative sign implies a negative relationship between the variable and strategy execution and a positive sign indicates a positive effect. NH = No *a-priori* hypothesis. [a]Refers to a more compensatory decision-making style. [b]Refers to a greater ability to regulate inhibitory control.

3.4 Summary

Table 1 summarises the hypothesised relationships between the variables within our framework. The parenthesised relationships refer to the compatibility hypotheses under investigation in our study while the un-parenthesised effects refer to known relationships between variables derived from the studies discussed in previous sections. The number of operators (i.e. minus/plus signs) indicate the amount of previous evidence supporting the relationship. Relationships for which there is a lack of extant findings and where we do not specify *a-priori* hypotheses, are denoted 'NH' and are estimated directly from the data.

4. Experimental Method

4.1 Design

In a 2 x 2 x 2 within-subjects design, we manipulated the prescribed decision-strategy (compensatory or non-compensatory), number of alternatives (3 or 5) and number of attributes (5 or 9). In addition to the experimentally manipulated variables, we included between-subjects measures for decision-style and inhibitory control.

4.2 Participants

Forty-eight individuals (35.42% female, n=17) were recruited through Amazon MTurk's online subject pool. Samples drawn MTurk are often used in behavioural studies and have been shown to perform on-par when compared to both student and expert samples (for a review on MTurk data quality see Buhrmester, Kwang, & Gosling, 2011). Mean participant age was 36.77 years (*SD* = 12.43). Highest level of education was, 22.92% high-school (n = 8) or professional diploma (n = 3), 45.83% undergraduate degree (n = 22) and 31.25% master's degree (n = 13) or doctorate (n = 2).

4.3 Materials and Measures

All experimental materials and data collection procedures were programmed in the software package outlined in Stoet (2010).

Compensatory Style Questionnaire. In order to measure self-reported decision-style, we employed Zakay's (1990) forty-item compensatory style questionnaire (CSQ). The CSQ is formulated as a bi-polar construct suggesting a subjective preference for compensatory decision-making at the higher end of the scale and non-compensatory decision-making at the lower end. Subjects were asked to indicate their agreement with items (e.g. "The correct manner to reach a decision is to treat the advantages and disadvantages of different alternatives as counterbalancing each other.") on a Likert-scale anchored at 1 (=completely disagree) and 5 (=completely agree). Previous applications of the CSQ have demonstrated high internal consistency and the composite measure has been shown to correspond with strategy use in unaided decision-contexts (Shiloh et al., 2001). The complete set of the CSQ items is reproduced in the online supplementary material (Appendix A1) for reference.

Eriksen Flanker Task. In order to measure individual differences in inhibitory attentional control, we employed a version of Eriksen and Eriksen's (1974) "flanker task" (EFT). The EFT is a widely used and extensively validated measure in cognitive psychology and is often used as the primary measure for assessing the inhibitory function of selective attention. It has been used in a variety of studies in the psychology of thinking and reasoning and more recently, it has been applied to the study of both micro and macro-economic decision-making (Carvalho, Meier, & Wang, 2016; Li et al., 2018). The EFT asks subjects to respond to arrays of arrows pointing in either the left (<) or right (>) direction. Subjects respond to the direction the central arrow is pointing in, by pressing a corresponding button on their keyboard. Arrows can be "flanked" by others pointing in the same direction (congruent, e.g. >>>>>>>>) or in the opposite direction (incongruent, e.g. >>><>>>). A consistent finding from the flanker paradigm is that individuals demonstrate slower response times (RTs) in the incongruent condition and the difference in RTs (i.e. $RT_{incongruent} - RT_{congruent}$) is interpreted as an individual's ability to regulate inhibitory control. For the purposes of the present study, we employ the relative difference in reaction times – averaged across four-hundred twenty experimental trials for each subject – as a between-subjects measure for inhibitory attentional control. Since OR readers outside of the B-OR community are likely unfamiliar with this task, examples of trials in the congruent and incongruent conditions as well as the detailed procedure followed for the EFT are provided in Appendix A2.

Choice Problems. In the main experimental task, participants were presented decision-problems in alternative by attribute matrices with differing combinations of alternatives and attributes (3x5, 3x9, 5x5 and 5x9). Choices involved the selection of a DVD player from within the choice set by applying a prescribed selection rule. The experimental task was loosely adapted from the adult decision-making competence (A-DMC) subscale for strategy execution (see for example, Bruine de Bruin, Parker, & Fischhoff, 2007). For the compensatory condition, subjects were asked to make their selection based on either an equal weight (EQW) or frequency-based heuristic (FRQ) and in the non-compensatory condition, deterministic eliminations by aspects (DEBA) or satisficing (SAT) (Alba & Marmorstein, 1987; Einhorn & Hogarth, 1975; Simon, 1955; Tversky, 1972). We chose these particular strategies as they have been found to be widely used by decision-makers in practice (Payne et al., 1993). Moreover, as a result of their relative simplicity, especially compared to more complex weighted additive difference models, we expected that a naïve subject pool would be able to easily understand and apply these to the choice problems that were presented. While a drawback to this approach is that the idiosyncrasies of the individual rules may be lost as a result of aggregating across the individual strategies – an issue we discuss in the results sections – it also allows us to obtain a more generalisable assessment of the differences between the strategies as a whole.

We made three main adjustments to the A-DMC subscale. First, while the A-DMC consists of ten choice problems with five alternatives and attributes, our choice problems included combinations of 3x5, 3x9, 5x5 and 5x9 alternatives by attributes. Second, for some choice problems, the A-DMC includes questions which contain an alternative that conflicts with the course of action suggested by the prescribed rule and dominates all other alternatives on every attribute. In order to remove any possible confounds relating to individuals' reliance on dominance rather than the prescribed selection strategy, we ensured that none of the choice problems contained a strictly dominating alternative and all other available options – i.e. apart from that suggested by the prescriptive procedure – performed better or equivalently on at least one attribute. Third, of the ten original A-DMC items, seven correspond to non-compensatory selection rules whereas three correspond to compensatory strategies (Bruine de Bruin et al., 2007; for the complete A-DMC along with all subscales see Liang & Zou, 2018). As a result, the original set of problems are skewed towards non-compensatory decision-strategies. In contrast, since our primary motivation was to compare the differences between prescribed compensatory and non-compensatory procedures, our experimental task was balanced equally for both sets of strategies with subjects making eight choices in the compensatory condition and eight in the non-compensatory condition, for a total of sixteen choices across the duration of the experiment. Sample choice problems are provided in Appendix A3.

4.4 Procedure

All participants were provided an information sheet explaining that they would be expected to complete a number of unrelated tasks testing their attention and decision-making ability. After providing consent for data collection and agreeing to participate in the study, subjects were directed to a standard demographic questionnaire and subsequently completed the CSQ and EFT. Both tasks were randomized across participants so that half of the subjects first completed the EFT while the other half completed the CSQ. This was primarily done to control for any order effects that may have occurred as a result of the sequence of tasks. The CSQ was presented in four blocks with ten items per block in a nearly identical format as used in previous studies (Zakay, 1990). The EFT included two practice blocks consisting of fifty trials in total and six experimental blocks with a total of four-hundred twenty trials (i.e. seventy trials per block). Participants were given a break between each block before moving on to the next sections. On average, this part of the experiment lasted between fifteen and twenty minutes. Next, participants were directed to the section of experiment assessing strategy execution. All subjects were provided additional instructions and were familiarised with the task by completing four practice questions applying each of the prescribed strategies (i.e. EQW, FRQ, DEBA and SAT) to a problem presented in a 3x3 alternative by attribute matrix. We employed an automatic exclusion criterion where subjects that failed to respond accurately to at least three of four questions, were directed to the end of the experiment. This was done to avoid including subjects that misunderstood the instructions. Subjects that met the inclusion criteria then completed the sixteen choice problems presented in randomized order. The duration of the entire experiment was between thirty and forty-five minutes.

4.5 Dependent Variable

An important consideration in most MCDM experiments is that of identifying a suitable dependent variable. This is one of the trenchant criticisms of previous studies that have investigated preferential choice problems (Bettman et al., 1990; Jacoby et al., 1974). The standard approach in such cases is to infer individuals' value functions, preferences and decision-strategies through directly examining, fitting and comparing competing models that adequately describe the choice data (Katsikopoulos, 2016). While such approaches provide some insights into the underlying choice process, they do not tell us much about the quality of choices themselves. An alternative approach is to measure choice quality by assessing whether individual choices respect strict dominance (Korhonen et al., 2018). This approach provides a more objective basis to assess the quality of a decision however, it is not particularly amenable to our purposes as strict dominance by its very nature is a highly non-compensatory cue – i.e. once a strictly dominating alternative is identified the choice is already determined and search terminated. Instead, we use a measure of *constructed dominance* as the dependent variable for the purposes of our analysis. Our conceptualisation of this form of dominance is similar to that articulated by Hogarth and Karelaia (2005) in their DEBA procedure, as well as Howard and Abbas (2015) in what they term 'deterministic dominance.' An important point of note however is that while Howard and Abbas's (2015) definition encompasses both strict (i.e. explicit dominance in the decision-environment) and constructed (i.e. dominance uncovered through the application of a deterministic decision-rule) forms of dominance, our measure for performance refers to the latter exclusively. It is difficult to argue for the value of any decision-strategy if its application is unable to uncover a dominance relation in environments where strict dominance is not otherwise apparent. Since our primary interest was in evaluating the effectiveness with which individuals can execute prescribed strategies, we employed simple correspondence as our criterion to assess choice quality. More precisely, a choice on the i^{th} decision-problem was considered to be dominating, if it corresponded to the solution obtained by applying the prescribed selection rule and dominated, if it did not.

4.6 Statistical Model

In order to exploit the mixed factorial design of our experiment, we employed a varying intercepts multilevel logistic regression model. This approach is particularly useful for our analyses as it allows us to simultaneously estimate the task level and subject level effects while also accounting for the (unobserved) heterogeneity of choices between subjects (for an overview this method see Gelman & Hill, 2006).

We labelled the selection of dominated responses, y_i as 1 and a dominating choice as 0 so that if modelled independently, $\Pr(y_i = 1) = logit^{-1}(\boldsymbol{X_i}\beta)$. That is, the model predicts the probability that a choice *does not* correspond to the solution suggested by the prescribed strategy. Our predictors included the number of alternatives (ALT), number of attributes (ATT) and decision-strategy (STRAT) at the task level (n = 768) and, inhibitory control (EFT) and self-reported decision-style (CSQ) at the subject level (N = 48). In addition, we included varying intercepts for subjects, $\alpha_{j[i]}$, where the subscript, $j[i]$ refers to the participant index for the choice i, made by subject j. Our hypothesised effects propose interactions between variables, however we omit the full vector-form representation of the model for aesthetic purposes and to conserve space. We adopt the notation scheme in Korhonen et al. (2018) and represent our $n\times K$ design matrix, $X = x_1,\ldots,x_K$ indexed by the set of linear predictors, $p = 1,\ldots,K$ and label the corresponding beta coefficients as $\beta_1,\ldots,\beta_K$. Our model can then be generalised as:

$$\Pr(y_i = 1) = logit^{-1}\left(\alpha_{j[i]} + \sum_{p=1}^{K} x_{ip}\beta_p\right), \text{ for } i = 1,\ldots, n.$$

$$\alpha_{j[i]} \sim N(\mu_\alpha, \sigma_j^2), \text{ for } j = 1,\ldots, N.$$

The error component, $\alpha_{j[i]}$ is assumed to follow a normal distribution and the mean (μ_α) and variance (σ_j^2) for the subject-level intercepts are estimated from the data. Essentially, $\alpha_{j[i]}$ acts as a shrinkage parameter on the estimates, explicitly accounting for the multilevel structure of the data by biasing the beta coefficients towards or away from the pooled population mean, depending on the distribution on $\alpha_{j[i]}$. If $\sigma_\alpha \to \infty$, the model is equivalent to a fully within-subjects specification and if $\sigma_\alpha \to 0$, the model reduces to the ordinary least squares (OLS) approximation.

5. Results

The following sections will present the main results from our analyses. We have chosen to primarily focus on the inferential process and report the summary results here. Technical details have been included in the supplementary materials (Appendix B).

5.1 Descriptive Statistics

We assessed the consistency of the CSQ by computing Cronbach's reliability metric. Overall, the CSQ demonstrated high item-wise consistency with a Cronbach's α = .81. The mean CSQ score across participants (*M* = 3.49, *SD* = .40) was above the midpoint of the scale suggesting that on average, subjects reported a higher preference for a more compensatory decision-style. This is in line with previous applications of this measure (Shiloh et al., 2001; Zakay, 1990). Next, we evaluated subjects relative ability to exercise inhibitory attentional control. We computed response time latencies for each subject between the congruent and incongruent trials on the EFT (i.e. $RT_{incongruent} - RT_{congruent}$). The mean latency between response times in the congruent and incongruent conditions was 75.64 milliseconds (*SD* = 29.27) and approximately normally distributed with a slightly fatter tail for slower mean RTs (skew = .06, kurtosis = –.52). Finally, we evaluated the number of dominated choices made by subjects on the strategy execution task. Overall, subjects made very few mistakes and on average, exhibited errors on less than five of the sixteen choice problems (*M* = 25.78%, *SD* = .44). This suggested that subjects were paying attention to the task and did not find the prescribed decision-rules too difficult to execute while, at the same time the errors that were made provided enough variability at the choice level to meaningfully test the hypothesized relationships.

5.2 Grouping Structure for Compensatory and Non-Compensatory Strategies

As is to be expected, there was variation between the individual rules with error rates ranging from (highest to lowest): FRQ (*M* = 32.81%, *SD* = .47), EQW (*M* = 28.65%, *SD* = .45), SAT (*M* = 24.48%, *SD* = .43) and DEBA (*M* = 17.19%, *SD* = .39). Since our hypothesized relationships dealt with compensatory (EQW and FRQ) and non-compensatory (DEBA and SAT) decision-strategies rather than the individual rules themselves, we needed to rule out the possibility that these differences in variation were highly idiosyncratic in nature. In other words, we needed to assess whether the data supported the grouping structure in our experimental design. We fit the model described in the previous section and included individual predictors for each of the four decision-rules (with FRQ as the reference category) to assess whether the mean error rates were significantly different across the individual rules. This analysis revealed that while error rates for FRQ and EQW were similar, both DEBA and SAT were significantly lower after controlling for the direct effects of the other independent variables. As an additional weak test for the suitability of grouping the individual strategies, we conducted a likelihood ratio test to assess whether a more complex model with four groups (FRQ, EQW, SAT and DEBA) was a better fit to the data than a sparse model with two groups (Compensatory and Non-compensatory). The more complex model did not improve explanatory power and was a poorer fit to the data (*LRT* $\chi^2(2) = 4.54$, p = .103, *ns*). We obtained similar support for models that included interactions between the task level variables. Taken together, the results from this analysis supported the grouping of the individual decision-strategies to formally test our hypotheses. A more detailed analysis for the effects of the individual rules is provided in Appendix B2.

5.3 Testing the Hypothesised Relationships

The complete results from our hypothesis tests are summarised in Table 2. Additional details regarding alternative model specifications are provided in Appendix B3, along with model evaluation in Appendix B4 (Cook, 1977; Gelman & Hill, 2006; Hair, Black, Babin, & Anderson, 2018).

As can be seen in Table 2, there was a substantial amount of variation in the subject level intercepts ($\sigma_j^2 = 3.29$), thus supporting our use of a varying intercepts model. Interestingly, once we accounted for the fixed effects of the task (no. of alternatives, criteria and decision-strategy) and individual variables (decision-style and inhibitory control), the unobserved subject level heterogeneity exerted very little influence. We can assess this aspect by comparing the difference between the marginal and conditional R^2 values (Nakagawa & Schielzeth, 2013). While the marginal R^2 refers to the variance explained by only the fixed effects in the model, the conditional R^2 also accounts for the additional variation that could be attributed to (unobserved) individual differences. In the present case, unobserved heterogeneity only accounted for an additional 2% of the variance at the data level.

Task Complexity. Hypothesis 1(a) and (b) proposed weak compatibility effects when it came to the role of the no. of alternatives and criteria on strategy execution. More precisely, we expected that increasing the number of alternatives and criteria would degrade choice quality for both compensatory and non-compensatory strategies, with this effect being less pronounced in the latter case. There was a large positive effect of the number of alternatives on the probability of selecting a dominated outcome. When we increased the number of alternatives from 3 to 5, subjects were 3.42 times more likely to select a dominated choice regardless of which strategy was prescribed (95%CI = 1.76 - 6.63, $p < .001$). The estimate for the non-compensatory condition was negative ($B = -.67$, OR = .51) and in line with our hypothesis, however the effect was not quite significant ($p = .081$). As a result, Hypothesis 1(b) was rejected.

The role of the number of attributes on strategy execution was more nuanced. Specifically, while in the compensatory condition, subjects were 2.39 times more likely to choose a dominated outcome when the number of criteria were increased from 5 to 9 (95%CI = 1.23 – 2.64, $p = .010$), in the non-compensatory condition the odds of selecting a *dominating* choice were increased by nearly the same amount. That is, in the non-compensatory condition increasing the number of criteria actually improved choice quality (OR = .22, 95%CI = .10 - .46, $p < .001$). Thus, we find partial support for Hypothesis 1(a) and our findings suggest that rather than a weak interpretation of compatibility, as long as the underlying preference structure remains unchanged, non-compensatory procedures are highly robust to the inclusion of additional criteria within the problem context and can improve the correspondence of choices with the recommendations of the prescribed decision-strategy.

This effect is visualised in Figure 1. The left-most panel demonstrates the interaction between the size of the alternatives by attributes matrix and the prescribed decision-strategy. It is apparent from the figure that the number of alternatives and criteria exert a distinct influence on strategy execution. This relationship is clearly demonstrated in the middle and right-most panels that highlight the disentangled roles of the number of alternatives and attributes. Note also that the interaction between the number of alternatives and attributes had essentially no effect on task performance.

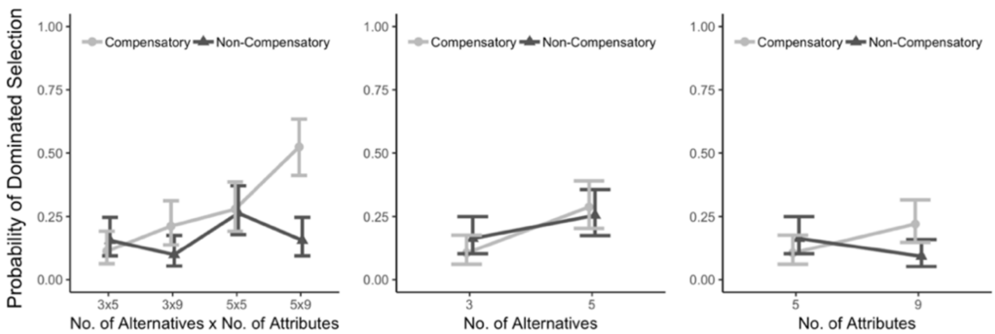

Figure 1. The effect of the number of alternatives and attributes on strategy execution in the compensatory (light-grey) and non-compensatory (dark-grey) conditions. The vertical bars represent the 95% confidence interval.

Table 2. Results from multilevel logistic regression predicting the odds of selecting a dominated outcome.

Level and Variable	Estimates		Odds-Ratios	
	B (SE)	z-value	OR	95% CI for OR
(Intercept)	-2.23 (.35)	-7.08***	-	-
Task Level (n = 768)				
STRAT (ref = Compensatory)	.50 (.36)	1.38	1.65	[.81, 3.37]
ALT (ref = 3)	1.23 (.34)	3.63***	**3.42**	**[1.76, 6.63]**
ATT (ref = 5)	.87 (.34)	2.56*	**2.39**	**[1.23, 4.64]**
ALT x ATT	.09 (.38)	.24	1.10	[.52, 2.30]
ALT x STRAT	-.67 (.38)	-1.74†	.51	[.24, 1.09]
ATT x STRAT	-1.52 (.38)	-4.03***	**.22**	**[.10, .46]**
Subject Level (N = 48)				
EFT	-.09 (.14)	-.65	.91	[.70, 1.19]
CSQ	-.89 (.15)	-5.96***	**.41**	**[.30, .55]**
Cross-Level				
EFT x STRAT	.56 (.19)	2.94**	**1.75**	**[1.21, 2.55]**
CSQ x STRAT	.08 (.21)	.38	1.08	[.72, 1.63]
Variance Component				
σ_j^2		3.29		
μ_α		.11		
Fit Statistics				
Log-Likelihood		-383.6		
Marginal R^2 (Conditional R^2)		.29 (.31)		

B = unstandardized regression coefficient, SE = std. error, z-value = test stat., OR = odds-ratio, 95% CI for OR = 95% confidence interval for odds-ratio, σ_j^2= variance of subject level intercepts, μ_α= mean for subject level intercepts, Marginal R^2 = Variance explained by the fixed effects, Conditional R^2 = Variance explained by full model, R^2 values were computed using procedure outlined in Nakagawa and Schielzeth (2013). *Note.* Significant odds-ratios are in bold.****p < .001, **p < .01, *p < .05. †p < .10 ns.* For ease of access, a full list of abbreviations is provided in Appendix C of the online supplementary information.

Decision-Style. Based on the rationale from Shiloh et al. (2001) and Zakay (1990), we formulated the expectation that compatibility between subjective decision-style and the prescribed decision-strategy would improve strategy execution (Hypothesis 2). While our analysis uncovered a significant direct effect of a higher self-reported tendency for more compensatory decision-making on overall task performance, the hypothesised interaction between a higher preference for compensatory decision-making and compensatory strategy execution was not supported (95%CI for OR = .72 -1.63, p = .704). As a result, we reject Hypothesis 2. While we cannot completely rule out that the overall effect was the result of a compatibility between a compensatory style and a compensatory task, the fact that we could not establish any discriminatory indication for this – i.e. a more compensatory style was associated with fewer dominated choices for both compensatory and non-compensatory strategies – suggests that an individual preference for compensatory decision-making may have more to do with the flexibility with which individuals can apply a range of decision-strategies rather than a specific reliance on compensatory or non-compensatory strategy execution.

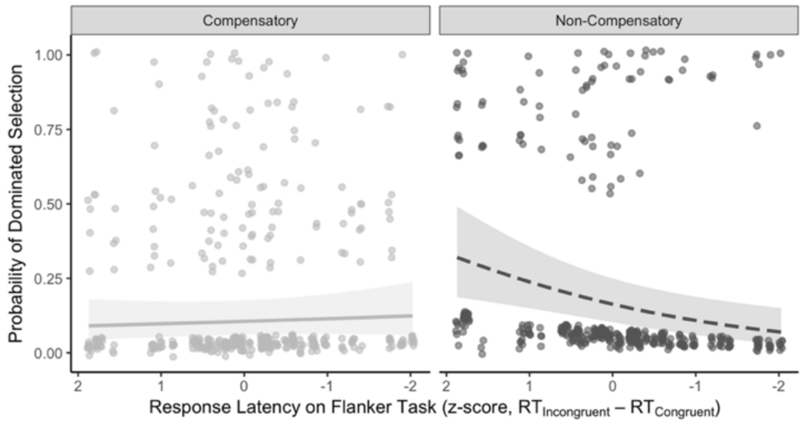

Figure 2. The effect of inhibitory control on strategy execution in the compensatory (light-grey) and non-compensatory (dark-grey) conditions. The translucent polygons represent the 95% confidence interval. The point estimates represent residual variance after accounting for the presence of other independent variables in the model. The x-axis is reversed and represents increasing inhibitory control. RTs are represented as z-scores for convenience (range = 129.85 to 16.94 *ms*).

Inhibitory Control. Hypothesis 3 suggested that individuals' abilities to regulate inhibitory attentional control would be positively related to performance on tasks that called for non-compensatory strategy execution. Our analysis suggested that a standard deviation increase in the mean response latency on the EFT – i.e. lower inhibitory control – increased the odds of selecting a dominated outcome by 1.75 times in the non-compensatory condition (95%CI = 1.21 - 2.55, $p = .003$). On the other hand, performance on the flanker task did not predict strategy execution in the compensatory condition, with an estimate that was marginally negative, non-significant and extremely close to zero ($B = -.09$, $p = .510$). Thus, Hypothesis 3 was supported.

As can be seen in Figure 2, the relationship between inhibitory control and performance on the strategy execution tasks markedly differs in the compensatory and non-compensatory conditions. Note that increasing response time latencies on the EFT (higher values for $RT_{Incongruent} - RT_{Congruent}$) are associated with lower inhibitory control. As a result, the x-axis is reversed so that the figure plots task performance as a function of increasing inhibitory control.

Table 3 maps the results from our analysis on the proposed theoretical framework and summarises the relationships between the variables under investigation. The number of operators serve as a schematic representation of the relative effect sizes for each of the independent variables (precise effect sizes are reported in Table 2 along with their associated 95% confidence intervals).

Table 3. Relationships between task and individual variables demonstrating the results from hypothesis tests contrasted between compensatory and non-compensatory decision strategies.

	Decision Strategy		Results	
	Compensatory	Non-Compensatory	Support	Compatibility Effects
Task Level				
No. of Alternatives	− − −	− −	No*	Partial
No. of Attributes	− −	++	Partial	Yes
Individual Level				
Decision Style	+	+	No	No
Inhibitory Control	null	+	Yes	Yes

Note. The negative sign implies a poorer performance and positive sign implies improved performance. The number of operators serve as a schematic representation of the effect size for each variable. *Not supported at 95% level (p = .081). Compatibility effects are partially indicated as the sign of the estimate corresponded to the expected relationship.

6. Discussion

In his often repeated metaphor explicating the notion of bounded rationality, Herbert Simon likens human decision-making to a scissors whose two blades represent attention-scarce agents and the complex environments that they operate in (Simon, 1990). OR is perhaps quite naturally placed at the intersection of these extremes, refining models and methods that can help draw the blades together and reasoning about instances in which they might diverge (Franco & Hamalainen, 2015). In this respect, the central insights from the “fast and frugal” paradigm presented by Gigerenzer et al. (1999) may not be all that alien to OR scholars and practitioners. Stark results demonstrating the predictive accuracy of highly intuitive non-compensatory decision-strategies suggest that these procedures might have the potential to become an indispensable addition to the decision-analyst’s toolbox, provided they are deployed in circumstances that are favourable for their use. In the present study, our primary motivation was to investigate the conditions in which synergies between individual, model and task features can improve strategy execution in aided MCDM contexts.

Importantly, our results highlight that once task characteristics are taken into account, there is hardly any discernible difference between the relative accuracy with which individuals can employ prescribed compensatory or non-compensatory selection procedures. Rather than the difficulty associated with executing a particular strategy – at least as far as this can be inferred from the accuracy with which it is employed in practice – the correspondence of choices with a recommended course of action depends to a much larger extent, on the requirements from the task at hand. Our results clearly demonstrate that in cases where the underlying preference relation remains unchanged, dominance structures implied by non-compensatory approaches can be more easily detected by decision-makers when additional criteria are introduced into the problem space. This novel finding, to the best of our knowledge, provides some of the first experimental evidence suggesting that non-compensatory decision-aids may find particularly robust applications in decision-contexts characterised by an abundance of attribute information where only a subset of attributes are highly salient. At the same time, we find that such strategies are not totally immune to degraded performance as a function of information load when the number of available alternatives is increased. While we uncovered weak evidence that this effect is partially moderated in the case of non-compensatory strategies, further research is required to assess whether this was a chance artefact or demonstrative of systematic differences between the strategies themselves. Even in its weak form however, this result suggests the assumption that non-compensatory decision-strategies are universally easier to execute, may not necessarily hold in circumstances where they are employed as prescriptive decision-aids.

Where do these strategy execution costs come from? Our findings highlight that an important determinant of the adeptness with which individuals can employ non-compensatory strategies relates to their ability to regulate inhibitory control. This makes both intuitive and theoretical sense if we consider that such strategies require decision-makers to actively ignore non-instrumental information even if it is available in the task environment (Gigerenzer & Goldstein, 1996; Goldstein & Gigerenzer, 2002; Katsikopoulos & Gigerenzer, 2008). Thus, while non-compensatory strategies may be less computationally expensive, they still require individuals to exercise attentional control and their ability to do so may have significant implications for the accuracy with which they can implement the recommendations of a "fast and frugal" decision-aid in practice. On this front, our results highlight the role that metacognitive processes can play in the facilitation of effective strategy execution, underlining that task performance is a function of compatible couplings between agent, model and environment interactions. While this latter notion, under the banner of 'situation awareness', is an important area of research in fields such as human-factors engineering and design psychology (e.g. Endsley, 2015; Flach et al., 2004), it is relatively underrepresented in the prevailing discourse in B-OR.

Our results partially converge with findings from Del Missier et al. (2010, 2012) – particularly once methodical differences relating to the non-compensatory skew of the A-DMC subscale is taken into account – and suggest that suppressing available information may be an inherently effortful activity. Furthermore, we build on this fundamental insight and demonstrate the boundary conditions for the role of inhibitory control on prescriptive strategy execution, highlighting that individuals' capacity to regulate inhibition is more instrumental for selective (non-compensatory) rather than more integrative (compensatory) modes of information processing. A potential way forward in cases where time or other operational constraints necessitate the use of these principles, is to supplement the application of non-compensatory decision-aids with efforts aimed towards training inhibitory control (Allom, Mullan, & Hagger, 2016) and automatizing selective information processing (Bröder & Newell, 2008). An important caveat related to this finding however, is the correlational nature of the evidence we have uncovered. While care was taken to minimise the occurrence of confounding factors by incorporating a carefully constructed mixed-factorial experimental design, future research should attempt ruling out the possibility of alternative causal explanations by replicating this result in naturalistic decision-making settings.

Finally, on the role of "basic tendencies", our results suggest that a general subjective preference for compensatory decision-making may be associated with a greater flexibility with which individuals can apply a variety of decision-strategies. This finding is somewhat contradictory to the intuition from previous studies that have proposed that a stable decision-style would prioritize a particular mode of strategy execution at the expense of the other (Shiloh et al., 2001; Zakay, 1990). Instead, our results suggest that a more compensatory decision-making style may be associated with general decision-making ability and provide very little additional qualitative insight into strategy execution. This result appears to align with the related notion that "fast and frugal" reasoning can be applied in both intuitive and deliberative modes of information processing (Kruglanski and Gigerenzer, 2011). A potentially fruitful line of enquiry for the future may be to investigate the latent factor structure of the CSQ. This could illuminate the role of a personal disposition towards a particular decision-style on the strategy execution process at a more granular level and reveal underlying relationships that may have been missed in the present analysis. On this latter point however, there is reason to be sceptical. While the search for personality correlates for aided decision-making remains elusive (O'Keefe, 2016), the lack of such findings could also suggest that individual decision-processes may be more sensitive to situational factors and transient individual states rather than prevailing personal dispositions. Indeed, this interpretation would in many respects conform to the core insight underpinning the "adaptive toolbox"– reinforcing the ultimate malleability and flexibility of ecologically rational.

7. Conclusion

In this paper, we have provided a review of the literature supporting the use of non-compensatory "fast and frugal" choice heuristics within aided MCDM settings. We have highlighted that the research strands in this area have investigated questions around the individual determinants of heuristic use (e.g. Bröder, 2003; Zakay, 1990), the practical and empirical validity of heuristic decision-models (e.g. Hogarth & Karelaia, 2005; Katsikopoulos, 2013) and the role of the decision-environment in facilitating (or impeding) heuristic use and performance (e.g. Payne et al., 1993; Rieskamp & Hoffrage, 1999). We have argued that these strands while synergistic, are also disjoint and in this study, have proceeded to organise them around the compatibility hypothesis suggested by Simon's (1955, 1971, 1990) seminal work on bounded-rationality.

With the growing evidence for the accuracy of "fast and frugal" models of choice in a number of decision-making contexts, it is apparent that these methods provide a wealth of opportunities for model supported decision-aiding interventions and should be taken seriously within the decision-analysis (and broader OR) community (Katsikopoulos, 2011; Katsikopoulos et al., 2018; Martignon and Hoffrage, 2002). Taken as a whole, our findings highlight that rather than a property of a particular decision-model, individuals' abilities to act in accordance with the recommendations derived from an heuristic-based decision-aid, has more to do with synergies between individual, model and task characteristics. Our findings therefore, strongly resonate with the central insight from the "fast and frugal" research program and highlight that there is no "silver bullet" for effective decision-making (Gigerenzer et al., 2011). As our results reinforce, decision-makers are adept at applying both compensatory and non-compensatory heuristics with relative ease, as long as the features of the task environment and the capabilities of the decision-maker are in alignment. At the same time, our results also underline the fact that some of the intuition suggested by the descriptive psychological theory, may not necessarily hold for prescriptive settings. In our view, due to its descriptive and prescriptive foundations (Kunc et al., 2016), B-OR research provides a great deal of promise to address such discrepancies, particularly where model supported interventions are concerned. Indeed, in light of the research from the "fast and frugal" paradigm over the past decade, *simple* may no longer be so hard to accept for the decision-analytic community (Hogarth, 2012). It is time to address the question of simple for whom and under what conditions.

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