

Opinion

The elusiveness of context effects in decision making

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Contextual features influence human and non-human decision making, giving rise to preference reversals. Decades of research have documented the species and situations in which these effects are observed. More recently, however, researchers have focused on boundary conditions, that is, settings in which established effects disappear or reverse. This work is scattered across academic disciplines and some results appear to contradict each other. We synthesize recent findings and resolve apparent contradictions by considering them in terms of three core categories of decision context: spatial arrangement, attribute concreteness, and deliberation time. We suggest that these categories could be understood using theories of choice representation, which specify how context shapes the information over which deliberation processes operate.

Context effect research in conflict

Imagine a person who chooses an expensive but lightweight bike over a heavier, cheaper one. How will the same person decide when faced with a large variety of bikes and not only two? The common assumption that there exists a fixed mapping between each choice option and a latent utility governing choices is violated in many situations. Instead, preferences are constructed based on the specific circumstances and set of available alternatives, resulting in **context effects** (see [Glossary](#)). For several decades, research on context effects had involved the discovery and analysis of new effects. This approach has recently hit a hard boundary as an increasing number of studies are casting doubt on the robustness, generality, and even the direction of major context effects. To date, a theory that is able to integrate these contradictory findings is missing.

We review prominent studies that challenge traditional context effect research and provide a system to categorize conflicting findings. Additionally, we argue that past theory development has overlooked an important aspect of the decision: the representation of choice options. We suggest that a theory of representation has the potential to account for many unexplained empirical findings. To guide future empirical research and theoretical development, we summarize key properties that a theory of representation should comprise to be able to synthesize context effect research.

The influence of context on decision making

Humans, non-human primates, and other animals are systematically influenced by contextual features, from low-level processes such as perception and attention to high-level ones such as decision making. Within the area of decision making, the social and biological sciences have been particularly interested in how the composition of the choice set affects preferences, giving rise to multi-alternative, multi-attribute context effects. For example, a **target** option appears more desirable if it is presented together with a **decoy** option that is substantially worse than this target (but not other options): a so-called **attraction effect** [1]. Context effects have gained popularity across disciplines as they tackle fundamental questions, such as whether human

Highlights

The study of how the composition of choice sets affects choices has been a thriving research topic for many years now. Among the many different context effects, the three main ones, attraction, compromise, and similarity effects, have been demonstrated across a wide variety of settings and species.

Research in recent years has shown that a variety of simple, seemingly irrelevant changes in the experimental setting can make each of the three main context effects disappear or even reverse. None of these effects seems to be compatible with existing theoretical approaches, or with each other, for that matter. Empirical research has far outpaced theoretical development.

The current approach to context-effect research has reached a hard boundary. The field needs a coherent synthesis of the existing literature and a research agenda that overcomes the past shortcomings.

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decision making complies with normative theories, how information is processed and choices are made, and how the brain represents decision variables such as value or utility.

As the term ‘multi-alternative, multi-attribute’ suggests, context effects usually involve more than two choice options that are each described on more than one attribute or dimension. In the most common case, individuals face a decision between three options described by two attributes, such as the choice between three road bikes that are equivalent except for their weights and prices. In the case of the attraction effect, two of the bikes would trade off weight and price, whereas the third would be heavier or costlier than one of the other options without compensating for it on the second dimension. [Figure 1A](#) (Key figure) depicts a 2D space in which the attraction effect and two other prominent context effects can be represented: the **similarity effect** [2] and the **compromise effect** [3]. According to the former, a nondominated similar option leads to a higher choice proportion for the dissimilar option and, according to the latter, an extreme option increases another option’s choice proportion by making it a compromise.

The vast but disconnected research on context effects

After numerous reports about species and situations in which context effects arise, from slime mold [4], frogs [5], honey bees [6], cats [7], monkeys [8], to various settings with human decision makers (e.g., [9–16]) and demonstrations outside the laboratory such as in online markets [17], research in the past few years has increasingly been characterized by cautionary findings that showed the boundary conditions of context effects (e.g., [18–22]). For example, research in both perceptual and preferential decision making has found that simply rearranging the information on-screen can make the major three context effects disappear or reverse [15,19,23].

Reports such as these are scattered throughout different fields, sometimes contradicting each other. Thus, a coherent synthesis (or even categorization) of context effects and their boundary conditions is currently missing. The present work aims to close this gap and to channel the vast but largely uncoordinated research efforts on context effects in decision making into a principled and theory-driven agenda. In what follows, we introduce the three non-mutually exclusive categories ‘spatial arrangement’ (illustrated in [Figure 1B](#)), ‘attribute concreteness’ (illustrated in [Figure 1C](#)), and ‘deliberation time’ (illustrated in [Figure 1D](#)), that are useful to classify how recent important studies have manipulated task features and demonstrated reversals of context effects.

We argue that existing cognitive and neuroscientific theories, which attempt to explain context effects using only the properties of the deliberation process, may not be able to account for the full spectrum of findings (and boundary conditions) associated with context dependence. Instead, we suggest that future theoretical work (and subsequent empirical analysis) should examine how task features influence the representation of choice options, that is, the information with which deliberation processes operate. More specifically, we propose that taking the precision of this representation into account can tie together the puzzling findings from the three categories and we provide a sketch of how such a theory could look like.

Spatial arrangement

There are many different ways of presenting information. When choice-relevant information is explicit and comprises of multiple attributes and options, it is often shown in a tabular format. Within this format, it is possible to present the options as separate rows and the attributes as columns or vice versa (top panels of [Figure 1B](#)). Indeed, both formats are used frequently, mainly determined by the number of relevant alternatives and attributes. If there are many options that differ (or are summarized) on few attributes, options are typically presented as separate rows. In the reverse case, with few options defined on many attributes, attributes are mostly presented in rows and

Glossary

Attraction effect: a context effect according to which a choice option that is clearly inferior to one other option increases the choice share of this superior option at the expense of other options.

Compromise effect: a context effect according to which an extreme option that makes one other option appearing as a compromise increases the choice share of this compromise option at the expense of other options.

Context effects: systematic changes in choice behavior depending on the composition of the choice set.

Decoy: the option that is specifically arranged within a choice set in order to increase the choice share of the target option.

Perceptual choice: tasks in which an objectively correct state of the world both exists and has to be inferred from the provided input.

Phantom-decoy effect: a context effect in which the decoy is not available for choice (i.e., a phantom) but nevertheless has an effect on individuals’ choices. The exact effect exerted by the phantom decoy depends on various factors such as when the unavailability of the decoy is communicated to the decision maker.

Preferential choice: tasks in which individuals choose according to their latent (i.e., for the experimenter unobservable) preferences. Adherence to normative principles is typically assessed using consistency across trials.

Process-tracing: a set of techniques such as eye tracking or mouse tracking that allow quantifying decisions as they emerge rather than just measuring their outputs in the form of choice proportions or response times.

Similarity effect: a context effect according to which an option that is similar (but not clearly inferior or superior) to one other option draws away choices from this similar option at the advantage of other options.

Target: the option within a choice set whose choice share is expected to increase within a given context.

Key Figure

Context effects and their dependence on three categories

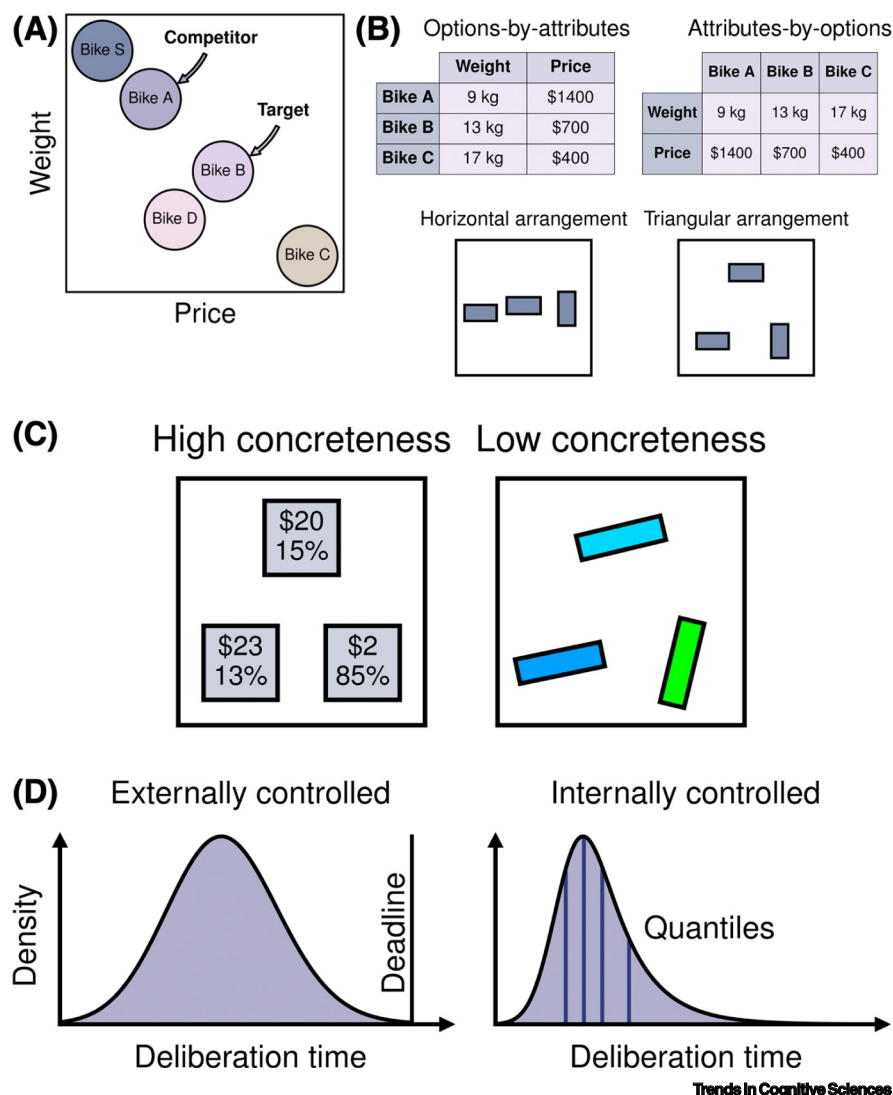


Figure 1. (A) Placement of the big three context effects in a 2D attribute space. Bikes A and B are characterized by two attributes, weight and price, and are presented together with one of the other bikes. The other bikes are designed to increase B's choice share relative to A, resulting in an attraction effect (Bike D), a compromise effect (Bike C), or a similarity effect (Bike S). (B) Top: two different spatial arrangements in a preferential task illustrating the compromise effect. Bottom: Two different spatial arrangements in a perceptual task illustrating the attraction effect. The horizontal arrangement produces mostly the attraction effect [15], whereas the triangular arrangement produces mostly the reversed attraction effect [19]. (C) Two different degrees of attribute concreteness illustrating the similarity effect. High concreteness (left panel) explicitly states the properties of the options, whereas in the low concreteness condition (right panel) individuals have to infer the properties of the stimuli (here, the potential gains and the associated probabilities are coded by the colors and orientations of the rectangles; see also [21,86,97]). (D) Internally and externally controlled deliberation time. Under internally controlled deliberation time, individuals decide when to make a decision and the response quantiles are analyzed. Under externally controlled deliberation time, there is a strict response deadline. Limiting the deliberation time appears to weaken the attraction and compromise effects but not the similarity effect [55,57,58].

options in columns. Given that both presentation formats convey the same information, most quantitative theoretical accounts treat the two presentation formats identically. This assumption seems to be incorrect: spatial arrangement has a substantial influence on how context influences choice.

A series of studies [22–24] contrasted a tabular attribute-by-option format against an option-by-attribute format using standard choice sets to elicit attraction, similarity, and compromise effects. Whenever options were presented in separate rows (Figure 1B, top left panel), attraction and compromise effects but reversed similarity effects were found. By contrast, a format in which options were presented in separate columns (Figure 1B, top right panel) led to similarity effects but weak or nonsignificant attraction effects and reversed compromise effects. Put differently, by transposing the matrix from which people extract identical information, two of the three major context effects reverse and the third disappears almost entirely.

Spatial arrangement influences context-dependent preferences in other settings as well. In recent years, the **perceptual choice** paradigm has become increasingly popular [15,19,25–29], in part due to the existence of an objectively ‘correct’ benchmark that the **preferential choice** paradigm lacks by definition. Additionally, the persistence of context effects in species like frogs and bees suggests that context dependence may be a fundamental phenomenon that extends beyond preferential choice to perceptual choice. Context effect research has almost exclusively focused on a task in which individuals have to identify the largest rectangle in a set of rectangles. However, this setting is just as susceptible to spatial-arrangement effects as tabular formats in the preferential-choice domain; The attraction effect has been found only when the stimuli are presented on a horizontal line close to each other (Figure 1B, bottom left panel; used in [15,19,26–28]), but it reverses entirely if the stimuli are arranged differently on-screen (Figure 1B, bottom right panel; used in [19]). While spatial-arrangement effects are not novel phenomena [30], prominent theories of context dependence are unable to explain why spatial arrangement influences choice.

Attribute concreteness

A second category relates to the richness of the options’ descriptions. Broadly speaking, we define ‘attribute concreteness’ as the degree of agreement about the attribute values across individuals and within the same individual across different points in time. If an attribute is quantified and presented numerically (such as the price of a product), there is very little disagreement about the amounts of its component attributes and, therefore, attribute concreteness is very high. By contrast, in the case of perceptual choices, for example, different observers perceive the objective characteristics of the same stimuli slightly differently (of course, in addition to the representation of the objective attribute amounts or perceptual quantities, preferential choices also involve subjective value-based transformations of the amounts and quantities that may be susceptible to other biases not discussed here). While there is consensus that concrete attribute presentation leads to robust context effects [29,31,32], many studies using less concrete attributes reported diverging results.

This is perhaps most pronounced in the earlier-mentioned rectangle-size task. None of the existing studies have reported a significant compromise effect [15,26,28]; the attraction effect, if found, has been substantially weaker than in the preferential choice domain [11,15,19,26–29,33]; the similarity effect has been shown to be quite strong both in the expected direction [15,26] and in the opposite direction [28]; and the **phantom-decoy effect** (an effect similar to the attraction effect in which the decoy is superior to the target but not available for choice) has been found to reverse [34].

Unsurprisingly, things do not improve when attribute concreteness interacts with individual heterogeneity in attribute valuation, as is the case in preferential choice. For example, it has been shown that replacing information such as ‘picture quality 5.5/10’ of a TV device with actual pictures with varying haziness nullifies the attraction effect [29]. However, this effect is not limited to photographic depictions of attribute dimensions. Other studies have reported that context effects in lottery decisions are mitigated if attributes are represented nonnumerically, using colors and orientations of rectangles (Figure 1C) or using rectangle heights and widths (Figure 1B) to represent lottery outcomes and probabilities [11,21]. That said, it is important to note that robust attraction effects have been observed with non-numeric presentation formats [22–24,35], though it is conceivable that spatial arrangement-based reversals of attraction effects documented in some of these experiments will not emerge when attributes are presented numerically.

Another line of research involves experience-based choices [36,37]. In contrast to decisions from description in which a summary of the relevant attributes is explicitly provided (e.g., \$4 with a probability of 80% or \$0 otherwise), individuals making decisions from experience observe realizations from the respective outcome distributions and thus have to infer the options’ properties. The randomness inherent to experience-based choices leads to variability in learning dynamics (within and across individuals), which in turn results in noisier values and, hence, lower attribute concreteness. While lottery-based tasks have been shown to elicit context effects in the description domain [2,10,11,38–40], these results do not seem to extend to the experience domain, at least in the case of attraction and compromise effects. The compromise effect reverses in experience-based settings [20] and the attraction effect is attenuated, disappears, or reverses [20,41,42]. The similarity effect is the only effect that is identical across description and experience [20]. Even though research on differences between description- and experience-based choices has been restricted to lottery-like options [43], attribute concreteness likely exerts a similar influence in other domains and in doing so alters attribute-based context effects.

Things get even more complicated in situations in which choice options do not have objective and easily discernible attributes, which is quite common in more naturalistic decision settings. One line of research has used food snack decisions, in which individuals first express their valuations of different foods and then make forced choices between them (e.g., [44–47]). Unlike most multi-attribute context effect experiments, researchers using this paradigm do not specify, manipulate, or model the locations of options in a multi-attribute space (Figure 1A). Rather, it is generally assumed that decisions depend on a single integrated value for each choice option [48]. The question relevant to context effect research then becomes: Does the value of a non-chosen option affect choices and, if yes, in which direction? It was found that the better the worst option in a choice set is, the less likely people are to choose the option with the highest value among the remaining options [49]. However, a failed replication of the original study [50] and reversals of this effect in a similar setting [51] cast doubt on whether choices that are based on integrated value representations reliably lead to context effects (but see [52,53] for an ongoing debate). Attempts with other naturalistic stimuli (e.g., movies) also failed to find robust context effects [29,54].

Deliberation time

Externally controlled deliberation time

The time course of decision making has been of core interest to the cognitive sciences for several decades now. Surprisingly, only few studies on context effects have explicitly investigated how deliberation time, externally controlled by an experimentally imposed response deadline (illustrated in Figure 1D, left panel) or internally controlled (individuals decide themselves when they make a decision; illustrated in Figure 1D, right panel), affects the occurrence and the strength of context effects. An early test [55] reported that limiting externally controlled deliberation time

reduced the preference for the compromise option. Along the same lines, more deliberation time increased the magnitude of attraction [56,57] and compromise effects [57]. Very high time pressure (1.5 s) in conjunction with a task of low attribute concreteness (Figure 1C, right panel) effectively eliminates the attraction and phantom-decoy effects [21]. By contrast, similarity effects occur even when individuals have only 250 ms to make a decision and become stronger with deliberation time [58] and occur in complex tasks of low attribute concreteness even under time pressure [59]. These results suggest that the similarity effect might be distinct from compromise and attraction effects, in line with a consistent pattern of the co-occurrence of the three big context effects across individuals: attraction and compromise effects tend to co-occur while at the same time inhibiting similarity effects [14,18,24,26,60].

Internally controlled deliberation time

Under externally controlled deliberation time, the evidence unequivocally suggests that context effects become stronger the more deliberation time individuals have. The picture looks different under internally controlled deliberation time, that is, when looking at choices based on how quickly the person decided to terminate the deliberation process to initiate an action. The standard approach to analyzing behavior in this setting is to split up the choice response times into different quantiles within each person and see how the choices vary as a function of quantile (illustrated in Figure 1D, right panel). The most comprehensive study so far [24] relied on a combination of previously published [15,23,28,61] and new data.

Across eight different experiments [24], the attraction effect became stronger with time, consistent with findings involving external time pressure. This pattern emerged mainly due to a reduced tendency to choose the competitor over time. Thus, the attraction effect observed on the aggregate level is a mixture of the reversed attraction effect in very fast decisions and the standard attraction effect in slower decisions. A qualitatively similar pattern was observed for the compromise effect with a later onset of the effect. Strikingly, the time-course of the similarity effect had exactly the opposite pattern: decision makers started the deliberation process showing a similarity effect, which developed over time into a reversed similarity effect. It is noteworthy that the table-transposition effects discussed earlier (see ‘Spatial arrangement’) influenced only the overall choice tendencies, but not their temporal development, suggesting that these two influences are independent from each other. The trends were qualitatively similar but heavily attenuated and substantially noisier in the nonpreferential-choice domain (spanning inference and perceptual tasks). In summary, attraction and compromise effects are affected by internal time pressure in a qualitatively similar way to external time pressure, whereas the similarity effect develops in the exact opposite direction.

A question of representation

The past two decades have seen the development of numerous quantitative cognitive and neurocognitive theories that explain the emergence of the attraction, compromise, and similarity effects, as well as other context effects (e.g., [10,58,62–67]). These theories are primarily theories of the deliberation process, which take the multi-attribute representations of options as given, specify a set of information sampling, valuation, and integration processes that operate over these representations, and predict how adding or removing certain options from the choice set alters evolving preferences and reverses choice (for an overview, see [68]).

As accounts of the deliberation process, these theories are incredibly useful. After all, they have been successful in explaining choices and response times in various studies that found the classical context effects [28,69]. However, a deliberation process by itself cannot easily explain transposition effects, or differences between perceptual, preferential, and experience-based

choice tasks. Additionally, although existing theories predict some simple deliberation time effects ([58,62,64]), they do not make an explicit distinction between internal and external control and cannot always predict how these effects reverse as a function of deliberation time.

We suggest that the boundary conditions summarized in this work could instead be understood in terms of how decision makers represent the underlying choice problem, that is, how the structure of the choice task determines the information about the choice options that is perceived, stored, and used in people's minds. In particular, it is conceivable that spatial rearrangement, reduced attribute concreteness, and high time pressure make it difficult for decision makers to obtain a rich and accurate representation that corresponds to the 'true' underlying structure of the choice situation. A theory of representation could specify how varying these aspects of the decision task changes the underlying representation of the options and indirectly influences preferences and choices. Importantly, such a theory of representation does not contradict existing theories of deliberation (e.g., [10,58,62–67]) but could be combined with them. That is, these theories could operate on (potentially inaccurate) representations where the attentional mechanisms proposed by some of these theories are used to form and refine the representations.

An outline of a representational theory

Although we are not proposing a specific representational theory in this article, the findings summarized in the preceding sections indicate a set of properties that such a theory needs to possess. Firstly, it must explain why attraction and compromise effects often co-occur and disappear or reverse together as spatial arrangement, attribute concreteness, and deliberation time are varied. Similarly, a representational theory must explain why the similarity effect is influenced in opposing ways and why it is more robust than the attraction and compromise effects. The similarity effect arises even among the fastest decisions, under high time pressure, and with options that have highly abstract attributes, whereas attraction and compromise effects take some time to develop, disappear under high time pressure, and are easiest to elicit with concrete, unambiguous attributes. Such an explanation could be linked to some preliminary suggestions in existing theories of decision making [62–64], which propose that similarity effects emerge naturally as attention fluctuates over choice attributes, whereas attraction and compromise effects emerge from the explicit comparison of attribute values and option preferences. It is possible that the latter are sensitive to task variables and associated representational structures and are thus both more susceptible to influences of the categories discussed here than the similarity effect (as well as positively correlated with each other).

A theory of representation that provides the foundation for deliberation theories to operate on has to be dynamic. In other words, it needs to develop as the choice unfolds. Such an approach has a long tradition in the cognitive sciences (e.g., [70–73]) and lies at the core of many existing context effect theories. However, this dynamic representation development would not track the deliberation process but rather the encoding of the options' attributes (e.g., using multivariate Gaussian distributions; illustrated in Figure 2). The assumption is that decision makers try to make sense of what options are available and how they are related to each other, which itself could be formalized as dynamic accumulation processes. Over the time course of a decision, this representation converges to the true state of the world and the uncertainty of the representation reduces. Whenever this uncertainty is (still) high (Figure 2A), it is difficult to detect dominance (necessary for attraction effects, see also [32,42]) and clear attribute orderings (necessary for compromise effects), inhibiting the respective context effects. However, the cardinal proximity of the options relative to each other is mostly independent from the other sources of uncertainty, such that similarity and similarity-like effects can develop earlier and be overridden as the precision of the representation of option-specific attributes increases (Figure 2B). Box 1 depicts a more technical

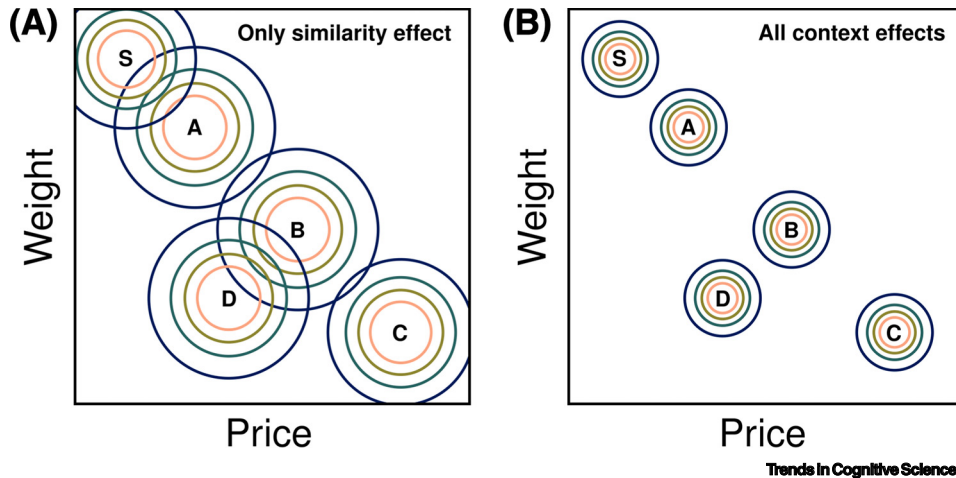


Figure 2. Example of a representational account of context effects We propose that the precision of representations is a critical determinant for the presence of different context effects. (A) In the case of short deliberation times or low attribute concreteness, people cannot form precise representations of the options' attributes, as reflected in the wide contour plots (note that these options refer to the bike options S, A, B, D, and C in Figure 1A). Consequently, the attraction effect is weakened because the representations are too imprecise for the detection of the dominance relationship between A and D. Similarly, the compromise effect is weakened because B does not always appear to be a compromise between A and C. However, the similarity effect can still occur as the dissimilar option B does not overlap with S. (B) With sufficiently long deliberation times and concrete attributes, the representational precision becomes high enough so that all context effects can occur. Although not shown here, we expect that spatial alignment would have similar effects on the precision of attribute representations. See Box 1 for more details.

description of how representational precision could affect context effects. Finally, different spatial arrangements can be expected to facilitate encoding of different aspects of the choice situation, such that different sources of uncertainty reduce faster than others.

Representation and the bigger picture

A noisy and dynamic joint representation of options and attributes offers conceptual tools with which to interpret **process-tracing** studies (e.g., using eye tracking; [74–78]). Eye movements might not only track the deliberation process but also the decision makers' attempts to reduce the uncertainty surrounding specific components of the joint distribution of options [79–81]. Broadly speaking, the categories proposed here determine how individuals make sense of the choice options and, consequently, which uncertainty to reduce. For example, the less obvious it is that options are, indeed, comprised of distinct attributes (e.g., in the case of the rectangle-size task, experience-based choices, or food snack decisions) or the less time is available to construct such a representation, the less people tend to actually try to reduce attribute uncertainty and instead focus on other components. Similarly, if the spatial arrangement of options induces fixation patterns that prevent decision makers from gaining precise representations of all options and their attributes, then context effects cannot be expected to occur robustly. Though beyond the scope of the present work, this idea could be applied to a whole set of other findings in which different sources of uncertainty within the joint distribution of representations are arguably affected (e.g., the influence of similarity on response times [82], the presence of common attributes without diagnostic value attributes [83,84], or overall context value [13,85–87]).

A representational theory of context dependence could draw upon the rich literature on mental representation and reasoning in other areas of cognitive science. One particularly promising avenue involves theories of structural alignment, which propose that object representations involve explicit relations between attributes and that reasoning processes involve attention to

Box 1. Mechanics of representational precision

The following simulations illustrate how precision could influence the decision maker's representation of the choice set and how the emergence of perceived choice set structures affect attraction, compromise, and similarity effects. We draw a single sample from the distribution of option representations (illustrated in Figure 2 in the main text) and observe how often that sample satisfies the necessary conditions for the various context effects to arise. Importantly, the simulations remain agnostic to the exact process that leads to context effects. It merely assesses whether the necessary conditions are fulfilled or not (hence, it is possible that the conditions for none and up to two context effects are satisfied at the same time).

The probability that a sample from the options' representation distributions satisfies the necessary conditions for each of the context effects in the three choice sets is depicted in Figure 1. In a setting with an attraction-effect decoy (choice set {A, B, D}), a high degree of precision will help the decision maker correctly identify the underlying asymmetric dominance relationship in the choice set. In other words, a sample from the distribution of A is likely to be better on both attributes than a sample from D, which is not the case for B. Low precision, however, will frequently distort attribute orderings and the decision maker is less likely to correctly identify dominance. Rather, the decision maker will be more likely to perceive a similarity structure (i.e., a sample from D is more similar to a sample from A than from B), reversing the attraction effect. Likewise, in settings with a compromise decoy (choice set {A, B, C}), a high degree of precision will help the decision maker to correctly identify the compromise relationship (i.e., the rank order is $C > B > A$ on one attribute and $A > B > C$ on the other one). A low degree of precision will lead to incorrect inferences and the compromise effect will often be overlapped by a similarity effect. Importantly, there is no pronounced effect of precision on the similarity effect (choice set {A, B, S}): regardless of precision, the decision maker will almost always be more likely to consider a sample from S to be more similar to a sample from A than from B. Only under extremely high levels of precision, the similarity effect could turn into a compromise effect as option A becomes more and more distinct from S and appears as a compromise between S and B.

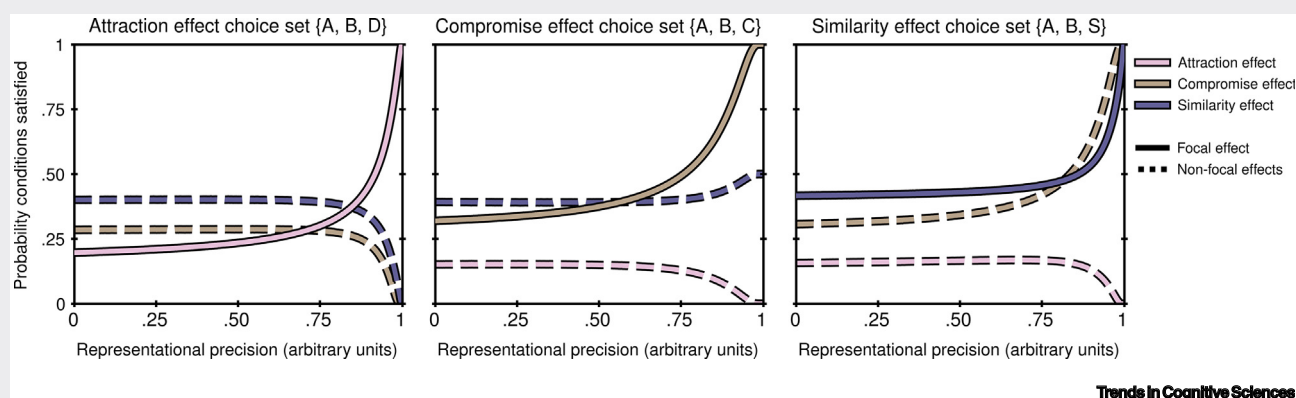


Figure 1. Effect of representational precision on context effects.

the commonalities and differences of relations [88]. For example, an option-by-attribute presentation format would likely make the features of choice options (e.g., the weights of bicycles) more alignable, which could facilitate their comparison and make dominance relations more apparent. Structural alignment theories have already been successfully applied to choice behavior [89,90] and it is possible that they could be further developed to explain reversals of context effects, particularly those generated by spatial rearrangement.

Empirical predictions and limitations

A theory of context effects that is based on representational precision makes specific predictions about how representation and the objective characteristics of the choice options interact with each other. Essentially, representational precision can be interpreted as the distances and degrees of overlap between the options in the mental attribute space, where a low precision can be compensated for by a larger objective distance. This prediction seems to be generally supported by existing manipulations of the objective distances in the attribute space in attraction effect choice sets ([10,19,60]; but see [91]). Along the same lines, whenever the decoy is chosen in situations in which it is only slightly worse than the target, it comes at the expense of the target and not the competitor [19], suggesting that (at least on some trials) the two options cannot be distinguished and are perceived to be equally desirable. An additional interesting prediction can be derived for the similarity effect: if the decoy option is not at the extreme end of the parameter

space (as typically used in the literature and illustrated here) but in between the two other options, the decoy would become the preferred option (i.e., the compromise option) under a sufficiently high level of representational precision.

Apart from these novel empirical predictions, there exist context effect phenomena that are not covered by the three categories introduced in this piece and that would require additional assumptions to fall within the scope of the sketch of a representational theory proposed here. For example, it has recently been shown that a sequential (as opposed to a simultaneous) presentation of stimuli can reverse attraction effects [33], that prior preferences determine in which direction the decoy affects choices [13,92], that an elimination procedure (instead of direct choices) reduces attraction effects [93,94], that context effects can be eliminated using explicit reference points [95], or that the degree of similarity between the target and the decoy has a non-monotonic effect on the attraction effect [96]. Moreover, only very few studies cover more than one of the presented categories [24]. Further empirical work is needed to set the scope of future theoretical developments and test the novel predictions of a representational account.

Concluding remarks

Context effects are ubiquitous and empirical research on context-dependence has guided the development of theories and models across numerous academic disciplines. However, recent findings are difficult to reconcile with existing theories. These findings involve manipulations of how options are arranged spatially, how concrete their attributes are, and how much time the decision maker has to decide. We summarize and synthesize these findings and suggest one approach to accommodate the observed results. We emphasize the role of representation, that is, how individuals perceive and store the structure of the choice task in their minds. The formation of representations takes place alongside (and even prior to) deliberation, determines the attribute values that are evaluated and aggregated during the decision, and, crucially, is sensitive to contextual factors like spatial arrangement, attribute concreteness, and deliberation time. A more detailed understanding of task representation is a promising topic for future work (see [Outstanding questions](#)) and we look forward to new theories that integrate formal models of representation with models of deliberation processes, providing a complete account of context dependence in decision making.

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Declaration of interests

No interests are declared.

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Outstanding questions

Is it possible to unite the existing empirical findings under the umbrella of a single theoretical account? Current approaches that rely solely on the deliberation process seem to have reached a dead end, with an increasing number of findings that they are unable to account for.

What are the mechanisms underlying effects of spatial rearrangement? There are substantial changes in behavior that are incompatible with current theories since the properties of the options do not change. Systematic applications of process-tracing techniques such as eye-tracking should provide critical insights.

How do people represent complex, abstract stimuli such as food snacks or other nonstylized realistic stimuli? Do people abstract specific attributes and, if yes, which ones? How do individuals adapt their strategies under time pressure and how can we explain the differences between time pressure they impose upon themselves and time pressure that is imposed from outside?

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