Cognitive Load in Economic Decisions*

Carlos Alós-Ferrer[†]
University of Zurich

Alexander Ritschel[‡]
University of Zurich

Anja Achtziger[§]
Zeppelin University Friedrichshafen

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Abstract

Intuitive decision making has a large and often negative impact on economic decisions, but its measurement and quantification remains challenging. Following research from psychology, behavioral economists have often attempted to causally manipulate the balance of intuition and deliberation by relying on experimental manipulations as cognitive load. However, these attempts have resulted in mixed success, with many null results and no clear general pattern. We explain the possible reasons behind these developments and offer avenues for improvement. First, we show that a very simple formal model of decision processes offers a straightforward test to determine whether cognitive load has been successfully induced, hence disentangling failed inductions and true null results. Specifically, cognitive load in complex decision tasks must result in shorter response times. Second, we show that the intuitive arguments on the behavioral implications of cognitive load do not hold on closer, formal examination, unless strong assumptions are made that may or may not hold in typical economic experiments. We then report on seven economic experiments (joint $N = 628$) using different cognitive load manipulations and confirm the implications of the model. Our research illustrates the differences between psychological experiments and economic tasks, and the difficulties associated with importing methods across fields.

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[†]Corresponding author: carlos.alos-ferrer@econ.uzh.ch. Zurich Center for Neuroeconomics (ZNE), Department of Economics, University of Zurich (Switzerland). Blümlisalpstrasse 10, 8006 Zurich, Switzerland. ORCID Number: 0000-0001-7207-9342.

[‡]Zurich Center for Neuroeconomics (ZNE), Department of Economics, University of Zurich (Switzerland). Blümlisalpstrasse 10, 8006 Zurich, Switzerland. ORCID Number: 0000-0001-5169-678X.

[§]Department of Political and Social Sciences, Zeppelin University Friedrichshafen, Am Seemooser Horn 20, D-88045 Friedrichshafen, Germany. ORCID Number: 0000-0002-1668-9784.

1 Introduction

Human beings routinely rely on their intuition, even for complex decisions. Extensive evidence from psychology shows that many human responses are based on impulses and habits, and involve little or no deliberation (Kahneman, 2003, 2011). Economic decisions are not an exception. Accordingly, the economics literature is paying increasing attention to the role of intuition in a large variety of areas. For instance, it has been often argued that self-control problems might be due to failures to inhibit intuitive reactions (Baumeister et al., 1994; Bernheim and Rangel, 2004; Kaur et al., 2010). These and other examples have given rise to a number of "dual-self" models (Thaler and Shefrin, 1981; Bénabou and Tirole, 2002, 2003, 2004; Benhabib and Bisin, 2005; Fudenberg and Levine, 2006, 2012), which reflect the view that economic behavior might result from the interplay between intuition and deliberation.

The role of intuition has also been intensely discussed for a number of important problems in interpersonal interactions. A large and heated debate has addressed whether cooperative behavior can be considered intuitive or not (Rand et al., 2012; Tinghög et al., 2013; Bouwmeester et al., 2017; Recalde et al., 2018; Alós-Ferrer and Garagnani, 2020). A similar debate has centered on whether fairness or rather selfishness is the default (intuitive) mode of behavior (Piovesan and Wengström, 2009; Fischbacher et al., 2013; Achtziger et al., 2016; Cappelen et al., 2016; Andersen et al., 2018). Several works have investigated whether honest behavior has an intrinsic value because dishonesty (and lying in particular) involves an active inhibition of intuitive tendencies (Cappelen et al., 2013; Fischbacher and Föllmi-Heusi, 2013; Gneezy et al., 2018). The recognition of the importance of intuition might also inform the design of behavioral interventions. For instance, Heller et al. (2017) designed randomized controlled trials to help youth at risk of engaging in crime "slow down and reflect on whether their automatic thoughts and behaviors are well suited to the situation they are in."

The study of intuition requires both correlational and causal evidence. Research suggests that deliberative processes rely on cognitive resources to a much larger extent than intuitive thinking (Baddeley and Hitch, 1974; Baddeley, 1992). Thus, if those cognitive resources are taxed or impaired, the balance between deliberation and intuition will be shifted toward the latter. This is the essence of *cognitive load* manipulations that causally reduce the amount of cognitive resources available for a task, hence impairing deliberation and boosting intuitive behavior. An extensive literature has shown the effectiveness of these manipulations (Baddeley et al., 1984; Shiv and Fedorikhin, 1999; Hinson et al., 2002; Lavie and de Fockert, 2005; Barrouillet et al., 2007). This is important both for psychology and for economics, because the shift induced by cognitive load would be very consequential in many real-life situations. In terms of decisions and performance, intuitive processes often correspond to cognitive shortcuts or heuristics, which might be aligned with deliberation in some or many situations, but might conflict with it, leading to biases, in economically relevant domains as decision making under risk or uncertainty. Thus, tilting the balance toward intuition allows to better understand such biases. In terms of preferences and motives, this might reveal intrinsic tendencies (sometimes informally referred to as a "default mode of behavior"), and hence a shift toward intuition might help uncover the roots of many economically relevant human tendencies as altruism or cooperation.

Inspired by psychological research, behavioral economics have turned to cognitive load and related manipulations to causally influence reliance on intuition. However, the literature has achieved limited success and generally obtained mixed or null results. Cappelletti et al. (2011) found no effect of cognitive load on proposer offers in an Ultimatum Game. Similarly, Cornelissen et al. (2011) found no effects in a Dictator Game, although there was an interaction with Social Value Orientation (Murphy et al., 2011). Hauge et al. (2016) reported finding small or nonexistent effects in a series of Dictator Games. Allred et al. (2016) studied strategic sophistication under cognitive load and concluded that the effects, if any, were inconsistent across the different setups they investigated.

Other studies, however, have found significant effects of cognitive load manipulations in economic tasks, sometimes in contrast with the studies quoted above. Milinski and Wedekind (1998) and Duffy and Smith (2014) found effects of cognitive load on behavior in a repeated prisoner's dilemma. Carpenter et al. (2013) provided evidence that cognitive load impaired strategic sophistication in games. Døssing et al. (2017) found increased cooperation under cognitive load in a repeated public good game. Schulz et al. (2014) used a series of mini-Dictator games and found that subjects under cognitive load react less to the degree of advantageous inequality. van 't Veer et al. (2014) found that participants under cognitive load were more honest in the die-rolling task of Fischbacher and Föllmi-Heusi (2013). Buckert et al. (2017) documented increased reliance on imitation under a manipulation closely related to cognitive load.

Overall, the picture is a blurred one, with mixed and often non-significant effects. It is also reasonable to assume that publication bias might have resulted in an additional number of unsuccessful studies not being circulated. In view of this, some researchers have even argued that economic rationality might be unaffected by temporary impairments in cognitive resources (Drichoutis and Nayga, 2020). Given the fact that cognitive load is a well-established, non-controversial manipulation in psychology, this situation is puzzling. In this work, we set out to provide answers to the puzzle and suggest avenues for possible improvement.

For this purpose, we first provide a very simple formal model of decision processes incorporating the postulated effects of cognitive load, namely that cognitive load tilts the balance toward more intuitive processes and away from deliberative ones. This simple model immediately delivers a useful prediction on whether or not a cognitive load effect might occur at all in a specific paradigm, which can help improve future experiments relying on cognitive load. The reason is that, if a given cognitive load experiment finds no effect, it is currently not possible to conclude whether the shift toward intuition was not as expected, or rather the cognitive load manipulation was simply unsuccessful. In particular, one cannot conclude whether the shift to intuition does not affect behavior because this behavior relies on automatic processes or because the particular cognitive load manipulation did not interfere with the appropriate cognitive mechanisms (e.g., inhibition processes) that were involved in the primary task (e.g., the Dictator Game; Forsythe et al., 1994). Our first prediction provides a manipulation check which allows to test whether or not the manipulation has been successful *independently of whether there are any effects on behavior.* Specifically, the model predicts that decisions under cognitive load must be *faster* than in its absence. The intuition for this result is straightforward. One of the fundamental characteristics associated with more intuitive (or more automatic) processes is that they are generally faster than more deliberative ones (Kahneman, 2003; Strack and Deutsch, 2004; Evans, 2008; Weber and Johnson, 2009; Alós-Ferrer and Strack, 2014). If a manipulation successfully induces a shift toward more intuitive processes, meaning that decisions arise from those more often, average response times must become shorter.

We remark right away that we are interested in economic tasks, which are comparatively complex. The straightforward prediction mentioned above, which we confirm in all our experiments, seems to have been missed in the psychological literature. The reason might be precisely the differences between the domains, and the fact that Economics often considers more complex decisions than psychology. Obviously, cognitive load is bound to cause a small, mechanical *increase* in response times (say, a few hundred miliseconds), because subjects are asked to keep something in memory or perform an additional task, and this will have effects on the more elementary processes of decision making, e.g. those involved in perception and motor implementation. Typical psychological tasks are often comparatively simple and involve very short response times, often below one second (e.g., categorizing a geometrical figure as a circle by pressing a key). In those tasks, the more mechanical effects of cognitive load might dominate, resulting in longer response times or little overall difference (Gevins et al., 1998; Baddeley et al., 2001; de Fockert et al., 2001). However, for complex tasks as the ones of interest to economists, the differences between the response times of more intuitive and more deliberative processes will be an order of magnitude larger than those arising from the mechanical effects of cognitive load. Thus, the former will dominate.[1]

Our model also allows us to critically examine the standard predictions ascribed to cognitive load in more complex experiments. Essentially, the argument is that, if cognitive load induces a shift toward intuitive processes, a shift toward intuitive actions should result. On close examination, this argument rests on additional and possibly unwarranted assumptions which we will describe next. The problem is that there are

[1]Suppose an intuitive and a deliberative process take on average 400 and 600 ms, and cognitive load mechanically slows down responses by 200 ms. It will be hard to see any effect of cognitive load on response times. Suppose that, instead, the average response times for the two processes are two and four seconds, respectively. The 200 ms mechanical delay is now negligible and can be safely ignored. We suspect that most tasks in cognitive psychology fall into the first case, and the reason that our prediction is easily confirmed in economic experiments is that they fall in the second case.

no intuitive or deliberative *actions*. Rather, there are intuitive or deliberative *processes*, which are in themselves unobservable and do not necessarily always select the same action. For the simple tasks often used in cognitive psychology, processes are often straightforward stimulus-response mappings with limited variability, e.g. the Stroop or Flanker tasks (Stroop, 1935; Eriksen and Eriksen, 1974), and an identification between intuitive processes and intuitive actions might be unproblematic. For the complex decisions economists are interested in, e.g., strategic interaction in the Ultimatum game, decision tasks requiring Bayesian Updating, or managers' behavior in oligopoly markets, however, processes are closer to behavioral rules, which depend on stimuli in a noisy way. For instance, a behavioral rule in a typical behavioral economic paradigm like the Ultimatum Game could be "reject the offer if you feel that the offer is unfair." What is perceived as "fair" might differ from subject to subject, and the threshold might not be a sharp one for a given subject. This rule obviously depends on the stimulus "offer," but in a noisy way because sometimes a subject might reject a certain offer (e.g., 3 out of 10) and other times the same receiver might accept the same offer (stimulus). It is simply not possible to conclude that a given action comes from a particular type of process without incurring in a reverse inference fallacy (Krajbich et al., 2015).

Further, even though theories of intuition and deliberation often use those labels in a dichotomous way for simplicity, the underlying dimension (automaticity) is actually viewed as a continuum in psychology (e.g., Allport, 1954; Schneider and Shiffrin, 1977; Shiffrin and Schneider, 1977; Cohen et al., 1990). That is, few processes are purely automatic (or intuitive), or, in other words, many processes that psychologists and economists might view as intuitive are merely *less* deliberative than others and rely *less* on cognitive resources than those. Thus, it is by no means clear that, even if cognitive load shifts the balance toward more intuitive processes, those more intuitive processes will remain completely unchanged under impaired cognitive resources. In our model, we incorporate natural assumptions on how decision processes are affected (be they more deliberative or more intuitive), and find that the standard predictions regarding the effects of successfully-induced cognitive load on behavior fail to obtain. Restoring them entails a strong, additional assumption which essentially boils down to intuitive processes being completely unaffected by cognitive load.

We propose that researchers interested in effects of cognitive load in future experiments deploy the response times test we provide here as a manipulation check, in order to be able to argue that their manipulation had the desired effect of inducing a shift toward intuition. At the same time, researchers of different domains should carefully think about the underlying strong assumptions on the nature of the involved intuitive processes on which the cognitive load effect rests. This is not to say that researchers in economics should abandon cognitive load, but merely that the nature of the assumptions on underlying processes should be made clear, and their validity should be investigated.

After detailing the findings in our simple model, in this paper we report on seven independent experiments (joint $N = 628$), using a variety of cognitive load manipulations and different applications with reasonably-complex tasks (strategic interactions in Cournot oligopolies, voting decisions in small committees, and belief updating tasks). In all experiments, we find robust effects of cognitive load on response times as predicted by our model. Hence, we conclude that all our cognitive load manipulations successfully induced process shifts as desired. However, effects on actual behavior are mixed and often nonexistent.

The remainder of the paper is organized as follows. Section 2 provides an overview of the psychological theories behind cognitive load manipulations. Section 3 spells out our formal model. We then present three experiments on strategic behavior in Cournot markets (Section 4), three experiments with different voting rules in committees (Section 5), and an experiment on belief updating with two different cognitive load manipulations (Section 6). Finally, Section 7 discusses the results and presents suggestions for future research.

2 Working Memory and Cognitive Load

Understanding cognitive load manipulations requires a discussion of *working memory*, which can be described as the set of functions and resources governing the selection and execution of decision processes. Hence, we briefly introduce the working memory model of Baddeley (1986, 1992, 1996, 2000), which is a standard reference in cognitive psychology. This model describes how different working memory components might be responsible for intuitive (often called automatic) and deliberative (often called controlled) processes and their selection. It suggests a supervisory system that controls the switch between processes. The model distinguishes a *central executive system* from several subordinate memory systems (components) that are modality-specific. These components are the *phonological loop*, the *visuospatial sketchpad*, and the *episodic buffer*. Each of the working memory components has only limited (cognitive) capacity. Accordingly, cognitive load manipulations work by overloading these components' resources.

The *phonological loop*, also known as *verbal working memory*, is responsible for the retention of verbally coded material, independently of whether it is presented in written or auditory form. It refreshes stored information through inner-voice repetition or subvocalization (see, e.g., Gathercole and Baddeley, 1993). The assumption is that the cognitive resources required by the phonological loop are used more intensely by more controlled processes. Most of the cognitive load manipulations employed in previous economic research target the phonological loop (typically, keeping certain numbers in memory), and accordingly, so did several of our manipulations. The *visuospatial sketchpad* is responsible for the retention of graphically coded material, as e.g. images. Some cognitive load manipulations in psychology avoid the phonological loop and target the visuospatial sketchpad instead by, e.g., asking participants to keep a configuration of dots in memory. One of our voting experiments (Section 5) included a manipulation of this type. The *episodic buffer* is the most-recent addition to working memory theory (Baddeley, 2000), and is assumed to be responsible for the temporary storage and manipulation of information retrieved from long-term episodic memory.

Last, the *central executive* integrates information from various sources and is also seen as the supervisor or controller of the other working memory components, consuming a large part of the cognitive resources associated with working memory (Norman and Shallice, 1986). It plays the role of a supervisory system switching between controlled and automatic processes. More generally, it is assumed to govern the controlled selection or development of strategies in situations which are new in the sense that no specific rules have yet be learned, i.e. when automatic processes are not available. It is also responsible for allocating attention to complex controlled processes and implementing them. Hence, successfully performing complex cognitive tasks (e.g. by inhibiting automatic processes) can be assumed to rely on functions of the central executive. Cognitive load manipulations targeting the central executive are seen as particularly demanding. The Bayesian Updating experiment in Section 6 included a manipulation of this type.

3 A Simple Formal Model

The model builds upon previous models incorporating multiple behavioral rules, but extends them to incorporate cognitive load (Achtziger and Alós-Ferrer, 2014; Alós-Ferrer, 2018; Alós-Ferrer and Ritschel, 2021). It assumes that two behavioral rules codetermine behavior, a more deliberative one and a more intuitive one. In this manuscript, we present multiple experiments in different settings involving different behavioral rules, and hence we keep our model abstract.

3.1 The Basic Model

Consider a given decision problem, where a decision maker has received some information on the available alternatives. On the basis of possibly-different parts of that information, different behavioral rules deliver prescriptions. Suppose further that only finitely many options are available (as will be the case in the experiments). Denote by X the finite set of options, with typical element $x \in X$.

In any cognitive load experiment, the researcher will have some candidate processes or behavioral rules capturing deliberative and intuitive behavior. Let D and I denote the more deliberative/controlled and more intuitive/automatic behavioral rules, respectively, and let x^D denote the deliberative and x^I the intuitive choice. However, behavior is noisy, and hence we assume that all rules are stochastic in nature, i.e., they carry an amount of noise, resulting in deviations from the rule's prescription. Note that, hence, the deliberative rule can select x^I and the intuitive one can select x^D, and any of them could select actions $x \neq x^D, x^I$. That is, x^D is the option most frequently selected by the deliberative process and x^I is the option most frequently selected by the intuitive process, but the processes themselves are noisy. If $P^D(x) > 0$ and $P^I(x) > 0$ denote the probabilities with which each rule selects $x \in X$, conditional on the rule being the one which actually determines the response, then $P^D = P^D(x^D)$ is the probability with which the deliberative rule indeed selects the deliberative choice, and $P^I = P^I(x^I)$ is the probability with which the intuitive rule selects the intuitive alternative. By definition of x^D and x^I, and assuming no knife-edge ties, one has that, for each decision situation, $P^D > P^D(x)$ for all $x \in X, x \neq x^D$ and $P^I > P^I(x)$ for all $x \in X, x \neq x^I$. That is, the prescription of a rule (x^D or x^I) is the rule's *most frequent* (modal) selection, but in the multi-alternative case this does not even imply that the prescription is selected more than half of the time.

If a researcher has decided to implement a cognitive load manipulation, it will be because he or she wants to make use of the fact that cognitive load induces a shift in (unobservable) decision processes. To formalize this assumption, we adopt the view that which of the two rules will actually determine behavior is a stochastic event. Let $\Delta > 0$ be the probability that the actual response is selected according to the more intuitive rule (or, alternatively, the latter is not inhibited by the central executive in favor of more deliberative ones), and $1 - \Delta$ the probability that it is selected according to the more deliberative one. The parameter Δ thus reflects the balance between more intuitive and more deliberative processes. The essence of cognitive load is hence captured by the following assumption.

(L) Δ increases under cognitive load.

Response times are also assumed to be stochastic. Let $R^D = E[RT|D]$ and $R^I = E[RT|I]$ denote the *expected* response times conditional on the response being selected by the more deliberative or the more intuitive rule, respectively. For simplicity, we assume that expected response times do not depend on the actually-selected response. Naturally, since the more automatic rule is thought to be faster *in expected terms*, we assume

(R) $R^D > R^I$.

For some of the results below, we will further assume that

(P) $P^I > P^D$,

i.e. the deliberative/controlled process is noisier than the intuitive/automatic one, while the latter is more *consistent*. This is natural since automatic processes are assumed to rely more strongly on associative stimulus-response patterns. A simple way to think of the model is to conceive of the intuitive rule as a swift cognitive shortcut, while the deliberative rule is a slow, deliberative process which depends on actual computations and is hence less consistent.[2]

[2] One should be careful with interpreting consistency in terms of errors. For instance, one might conclude that since the automatic process is more consistent, it is less "error-prone" and hence superior to the deliberative one. This view would be wrong. If a process does not select its modal answer, this is not necessarily an error in the normative sense. For instance, whenever the intuitive rule's modal response x^I corresponds to a normatively-incorrect bias, the higher consistency of this process means that it is very often wrong (and very fast at that).

The model described so far encompasses the one in Achtziger and Alós-Ferrer (2014), which however was restricted to binary choices, and extends it to include cognitive load. Assumptions (R) and (P) have been given a micro-foundation in Alós-Ferrer (2018), where the behavioral rules are instantiated as diffusion processes as in the drift-diffusion model (DDM) of Ratcliff (1978) and Ratcliff and Rouder (1998), which has been recently further analyzed by Fudenberg et al. (2018) and is standard in cognitive psychology and neuroscience (e.g. Shadlen and Shohamy, 2016). In this model, evidence accumulation (internal to the decision maker) is captured as a diffusion process with a trend μ and two barriers. Whether the process chooses an option or the other corresponds to whether the upper or the lower barrier is hit first. The response time is the time at which the first barrier is hit. Alós-Ferrer (2018) shows that assumptions (R) and (P) above follow immediately if one assumes that the drift rate of the more automatic process is larger in absolute value than the drift rate of the more deliberative process, which in turn simply captures that the former is swifter than the latter.

It is important to emphasize that the response time of a given behavioral rule can never be actually observed, because any given choice (even if it is the choice most likely selected by a given rule) might originate from any behavioral rule. Thus, predictions can not rely on an assignment of choices to rules without falling prey to a reverse inference fallacy (Krajbich et al., 2015). This problem can be avoided by concentrating on averages which do not condition on particular choices (e.g., response times under high vs. low cognitive load, across all decisions). A different way to derive testable predictions rests on the concepts of *alignment* and *conflict*. Recall that x^D and x^I are the choices made more often by the rules D and I, respectively. In this sense, they are the *prescriptions* of the rules, even if those do not always select them. We speak of *conflict* if the behavioral rules make different prescriptions ($x^D \neq x^I$), and of *alignment* if both behavioral rules make the same prescription ($x^D = x^I$).

This distinction is important. First, in some experiments, the prescriptions of the behavioral rules might be clear beforehand, hence observable. For example, a myopic best reply can be computed *ex ante*, even if a noisy best-reply rule does not always select it. An imitative rule will prescribe to follow the alternative with the highest observed payoffs, even if the actual choice sometimes deviates from that prescription. A rule approximating normatively optimal behavior will deliver clear prescriptions, even if the actual rule is error-prone. Thus, once the experimenter has focused on two particular rules, whether a specific decision happens under conflict or under alignment might be *ex ante* observable.

Second, in any experiment relying on cognitive load, the assumption is that the shift to more intuitive processes will result in an observable change in behavior. This might not always be the case, however. Intuitive processes are in themselves not flawed: rather, they have evolved because they economize cognitive resources while delivering a good response in evolutionarily typical situations. In many cases, the intuitive process (e.g., reinforcement, imitation) will actually prescribe the same response as more deliberative processes (e.g. Bayesian Updating, optimization), i.e. both processes are in alignment. However, when they are used in an evolutionarily new situation, they might conflict with the latter and prescribe erroneous or suboptimal responses.[3] In particular, no effects on behavior (e.g., performance impairments) should be expected in a situation of alignment because intuitive and deliberative processes point to the same option.

For instance, reinforcement learning relies on previous experiences and applies them to a new situation. A simple "win-stay, lose-shift" rule that just repeats behavior which led to a success (say, positive payoffs in a binary-outcome paradigm) can be expected to be highly automatic. In many cases, simply repeating successful behavior will differ from the prescription of more deliberative rules, e.g. optimization based on Bayesian updating of beliefs (Achtziger and Alós-Ferrer, 2014) or (myopic) best reply in an interpersonal strategic situation (a game; Alós-Ferrer and Ritschel, 2018). Those are cases of conflict. However, in some cases, depending on prior beliefs or the strategic structure of the interaction, the deliberative rules might also prescribe to repeat the previous choice. Those are cases of alignment, where reinforcement acts as a cognitive shortcut. In these cases, no effect on performance should be expected if the deliberative processes are impaired.

3.2 Response Times Effects

Our first result is straightforward. Even though the response times of individual processes (conditional on process selection) are unobservable (because any choice might have been selected by any process), observable response times are a convex combination of the response times of the different processes. The effects of cognitive load on response times for tasks in the economic domain are then rather intuitive. Cognitive load shifts the balance toward more impulsive/automatic processes, that is, the percentage of decisions accruing to such processes increases. Since automatic processes are faster, one immediately obtains the apparently paradoxical conclusion that response times must *decrease* under cognitive load. This is captured by the following straightforward result.

Theorem 1. *Assume (R) and (L). Under cognitive load,*

(H1a) the expected response time decreases; and

(H1b) the expected response time conditional on either conflict or alignment decreases.

Proof. The expected response time is $(1-\Delta)R^D + \Delta R^I = R^D + \Delta(R^I - R^D)$. Since $R^I < R^D$ by (R), this quantity decreases under cognitive load by (L). This is independent of whether one conditions on conflict or alignment. □

[3] Suppose x^D is normatively correct in a pre-specified sense (derived from the specific application). For decisions under alignment, the intuitive rule is a cognitive shortcut which delivers the correct response more often (and faster) than the deliberative one. However, for decisions under conflict, the intuitive rule very often results in an error.

Note that (H1b) is still true if one allows for differences in Δ across conflict and alignment situations (for instance, it might be reasonable to assume that Δ is smaller in case of conflict, reflecting conflict detection and resolution by the central executive). In this latter case, (H1a) also holds, provided the experiment avoids confounds which would alter the proportion of decisions of each type across cognitive load treatments. As we will show below, behavioral effects under cognitive load should only be expected (if any) in case of conflict, and hence we consider it preferable to concentrate on the conditional prediction (H1b) in experiments where the distinction between conflict and alignment is observable, and revert to (H1a) if not. In the experiments we report on below, we will face both kinds of situations.

We also remark that, to keep the model simple, we have assumed that *process* response times in themselves are unaffected by load. This can be easily generalized. In particular, a natural model of cognitive load in terms of drift-diffusion processes would be to assume that the process barriers are lowered, resulting in lowered process consistency (more randomness). This immediately results in *faster* process response times, which adds to the effect shown above.

As already commented, in tasks proper of cognitive psychology (go/no go, Stroop, flanker, etc.), where response times are extremely short, in practice the effect identified in Theorem 1 is likely to be small and other, more mechanical effects might dominate. However, we focus on economic tasks, which are typically more complex and associated with longer response times. for those, mechanical effects (typically measured in hundreds of milliseconds) are likely to be negligible. Indeed, shorter response times under cognitive load have been observed in a few studies using complex tasks (most cognitive load studies in economics do not report response times). Specifically, Whitney et al. (2008) observe this effect in a study on framing under phonological-loop cognitive load, and Gerhardt et al. (2016) report shorter response times in lottery choices when using a cognitive load manipulation targeting the visuospatial sketchpad. However, those studies investigated a different research question than our paper and did not provide a formal model that could explain the shorter response times under cognitive load.

3.3 Behavioral Effects

The effect of cognitive load on choice frequencies, however, is less than straightforward. It is often argued that cognitive load should increase the frequency of those decisions "prescribed" (i.e., most frequently selected) by the more impulsive behavioral rules. This intuitive conclusion, however, depends on additional assumptions and might be false in general. To substantiate this claim, we start by noting that, in addition to the process shift captured by (L), cognitive load is by definition likely to affect choice frequencies for individual processes. This is because, according to the literature reviewed in the previous section, processes relying on cognitive resources are selectively *impaired* by cognitive load and cannot work as in its absence. This leads to the following assumption.

(B1) P^D decreases strictly under cognitive load, and $P^D(x)$ increases weakly for all $x \neq x^D$.

This assumption states that the more deliberative behavioral rule becomes more noisy, hence selecting the deliberative (modal) choice less often (and all other options at least as often). In the domain of cognitive psychology, where automatic processes are often pure stimulus-response reflexes, it is also natural to assume that those processes do not rely on cognitive resources at all and should be completely unaffected by cognitive load. However, even though dual-process theories often speak of deliberative and automatic processes for simplicity, the automaticity dimension is actually viewed as a continuum (e.g., Schneider and Shiffrin, 1977; Shiffrin and Schneider, 1977). The actual postulate is that decision processes in the human mind differ in their degree of automaticity. We subscribe the view that, in more economic tasks, the intuitive rule of interest is a *more* automatic behavioral rule than the deliberative rule (hence our assumptions (R) and (P)), but we would not assume that it is void of any cognitive/deliberative content.

Alas, if the intuitive behavioral rule can also be affected by cognitive load, then no predictions can be made in terms of choice frequencies, as the following example shows.

Example 1. *Consider a situation of conflict,* $X = \{x^D, x^I, y, z\}$ *with* $x^D \neq x^I$*. Let* $P^D = 0.4$*,* $P^D(x) = 0.2$ *for all* $x \neq x^D$*,* $P^I = 0.7$*, and* $P^I(x) = 0.1$ *for all* $x \neq x^I$*. Denote choice probabilities under cognitive load with the subscript L. Let* $P^D_L = 0.25+3\varepsilon$*,* $P^D_L(x) = 0.25 - \varepsilon$ *for all* $x \neq x^D$*,* $P^I_L = 0.4$*, and* $P^I_L(x) = 0.2$ *for all* $x \neq x^I$*, with* $0 < \varepsilon < 0.05$*. Further, let* $\Delta = 0.25 - \delta$ *and* $\Delta_L = 0.5$*, with* $-0.25 < \delta < 0.25$*. This example fulfills (L), (B1), and (P) both with and without cognitive load. Further,* x^D *is the modal response of the deliberative process both with and without load, and analogously for* x^I*. The probabilities of an intuitive choice with and without cognitive load are*

$$\begin{aligned} P(x^I|\textit{Load}) &= 0.25 - \varepsilon + 0.5(0.4 - 0.25 + \varepsilon) = 0.325 - 0.5\varepsilon, \\ P(x^I|\textit{No Load}) &= 0.2 + (0.7 - 0.2)(0.25 - \delta) = 0.325 - 0.5\delta. \end{aligned}$$

Thus,

$$P(x^I|\textit{Load}) - P(x^I|\textit{No Load}) = 0.5(\delta - \varepsilon)$$

which can take positive, negative, or zero values in the admissible ranges of ε, δ*.*

The conclusion that cognitive load should lead to more intuitive choices in case of conflict, however, can only be reached under the strong additional assumption that the intuitive rule is purely automatic and hence unaffected by cognitive load.

(B2) The probabilities $P^I(x)$ are unaffected by cognitive load.

The following result makes this observation explicit. However, we remark that we do not expect the data to conform to this prediction without further ado, because we consider (B2) unwarranted in general.

Theorem 2. *Assume (P) holds with and without cognitive load. Under (L), (B1), and (B2),*

(H2) in case of conflict, the frequency of intuitive choices increases under cognitive load.

Proof. Let all probabilities under cognitive load be denoted with the subscript L. The probability of intuitive choices under cognitive load is

$$P(x^I|\text{Load}) = (1-\Delta_L)P_L^D(x^I) + \Delta_L P^I = (1-\Delta_L)P_L^D(x^I) + (\Delta_L - \Delta)P^I + \Delta P^I$$

where $\Delta_L - \Delta > 0$ by (L) and the probability of x^I under the intuitive process is unaffected by load by (B2). Note that $P^I > P_L^D > P_L^D(x^I)$ by (P) and the definition of x^D. Hence,

$$P(x^I|\text{Load}) > (1-\Delta)P_L^D(x^I) + \Delta P^I \geq (1-\Delta)P^D(x^I) + \Delta P^I = P(x^I|\text{No Load})$$

where the second inequality follows from (B1). □

As commented above, no performance impairments should be expected when the automatic rule actually acts as a shortcut supporting the deliberative one (alignment). Formally, even under the strong assumption (B2), the prediction of Theorem 2 does not extend to situations of alignment, as the following example shows.

Example 2. *Consider a situation of alignment,* $X = \{x^D, y, z, w\}$ *with* $x^D = x^I$*. As in the previous example, let* $P^D = 0.4$*,* $P^D(x) = 0.2$ *for all* $x \neq x^D$*,* $P^I = 0.7$*, and* $P^I(x) = 0.1$ *for all* $x \neq x^D$*. Denote choice probabilities under cognitive load with the subscript L. Let again* $P_L^D = 0.25 + 3\varepsilon$*,* $P_L^D(x) = 0.25 - \varepsilon$ *for all* $x \neq x^D$*, with* $0 < \varepsilon < 0.05$*, and* $\Delta = 0.25 - \delta$ *and* $\Delta_L = 0.5$*, with* $-0.25 < \delta < 0.25$*. Contrary to the last example, assume* $P_L^I(x) = P^I(x)$ *for all* $x \in X$*. This example fulfills (P) both with and without cognitive load, and also (L), (B1), and (B2). The probabilities of an imitative choice with and without cognitive load are*

$$\begin{aligned} P(x^I|Load) &= 0.25 + 3\varepsilon + 0.5(0.7 - 0.25 - 3\varepsilon) = 0.475 + 1.5\varepsilon \\ P(x^I|No\ Load) &= 0.4 + (0.7 - 0.4)(0.25 - \delta) = 0.475 - 0.3\delta. \end{aligned}$$

Thus,

$$P(x^I|Load) - P(x^I|No\ Load) = 1.5\varepsilon + 0.3\delta$$

which again can be positive, negative, or zero in the admissible ranges of ε, δ*.*

Theorem 2 and Examples 1 and 2 show that, in economic multi-alternative decision making, cognitive load might often fail to produce measurable results on choice frequencies. First, the natural hypothesis in the choice domain follows only if the strong assumption (B2) is made, or equivalently if the postulated intuitive process is of purely automatic nature, that is, it places no demands on cognitive resources (or, by continuity, very low demands). Second, even under that assumption, the result only follows in case of conflict and might not obtain if conflict and alignment are not clearly distinguished. This observation is of independent interest given that cognitive load manipulations have often failed to deliver results in economic experiments.

In summary, we view the strong prediction (H1a,b) derived from Theorem 1 as a manipulation check which can be used to verify that cognitive load was successfully implemented. Once this is established, we view the additional prediction (H2) derived from Theorem 2 as a test of the additional assumption (B2) on the nature of the intuitive behavioral rule.

4 Experiments 1–3: Cournot Oligopolies

In this section we discuss three different experiments where participants took the role of firm managers in Cournot oligopolies. In this setup, each participant acts as manager of firm and needs to decide how much of a good the firm is going to produce for the next period. Overall, four firms will supply the market with their goods and the total supply will determine the market price of all goods, hence, the profit each firm earns. The strategic interaction lies in accounting for the other firms who also supply goods to the market, e.g. to avoid "flooding" the market resulting in a very low price or producing more goods to make large profits when the price is high.

In this particular strategic setting, previous evidence suggests that two specific behavioral rules are particularly important. On the one hand, the firms could react to the actions of the other firms and calculate the profit-maximizing quantity assuming the other firms will provide the same amount of goods in the next period. This is known as *myopic best reply*, which captures one-step payoff maximization and can be seen as a simple proxy of deliberative thinking. On the other hand, a large strand of research has suggested *imitation* of successful strategies, e.g. producing the quantity which yielded the highest profit in the previous round, as an alternative rule governing people's behavior. Theoretical results by Schaffer (1989) and Vega-Redondo (1997) have shown that imitation in Cournot oligopolies mimics maximization of relative payoffs, which means firms focusing on making more profits than the competitors regardless of the overall absolute profits. These authors also showed that if firms follow imitative behavioral rules and make infrequent mistakes, the resulting stochastic dynamics converges to the competitive (Walrasian) equilibrium in which all firms earn zero profits (and not to the Cournot-Nash equilibrium in which neither firm can increase their realized profits by producing a different quantity). A number of laboratory experiments on Cournot oligopolies have found partial convergence to Walrasian outcomes, which can be taken as indirect evidence for the presence of imitative behavior (Huck et al., 1999; Offerman et al., 2002; Apesteguía et al., 2007, 2010). Buckert et al. (2017) conducted a Cournot oligopoly experiment adding an additional task which required attention in some trials (which could be interpreted as a form of cognitive load), and found evidence compatible with increased reliance on imitation. However, Bosch-Domènech and Vriend (2003) found no stronger reliance on imitation in a Cournot oligopoly experiment when cognitive demands were increased by implementing time limits and describing payoff tables in an inconvenient way. Alós-Ferrer and Ritschel (2021) measured response times in a Cournot oligopoly experiment and found evidence of multiplicity of behavioral rules along the lines of myopic best reply (i.e., reacting optimally to previous actions of others) and imitation (i.e., copying the action which yielded the highest payoff among all players).

In all three experiments below, the prescriptions of myopic best reply and imitation can be determined *ex ante* for each individual decision. Thus, tests can be made conditional on conflict or alignment. The experiments used different secondary tasks (i.e., cognitive load tasks) and within vs. between designs. For ease of exposition, we first present the shared experimental design and then the cognitive load manipulations. Finally, we discuss the results for response times (predictions H1a,b) and choices (prediction H2) for all three experiments.

4.1 Shared Experimental Design

Participants in Experiments 1–3 interacted in 4-player Cournot oligopolies (tetrapolies). The design (except for the cognitive load manipulations discussed in the next subsection) followed Alós-Ferrer and Ritschel (2021). Subjects participated in three different oligopolies (parts), with 17 rounds each (total of 51 rounds). For each part, we computed a payoff table representing possible profits in the Cournot market according to the amount of goods the firms produce. During the experiment a neutral framing was used and neither firms nor quantities were mentioned. We reduced the action space to four possible actions, i.e. A, B, C, and D with either increasing or decreasing quantities from A to D.[4] Hence, the whole payoff table had dimensions 4×20, with four rows representing the possible actions and 20 columns labeled AAA to DDD representing the possible actions of the opponents.

Payoffs were expressed in points, with an exchange rate of 20 Eurocents per 1000 points. The points achieved in all 51 rounds were accumulated and paid at the end of the experiment. After the first round the participants were informed about the outcome of the previous round. Before making the next choice, participants saw the full payoff table, their own choice and earnings from the previous round, and the previous choice and earnings from the other three group members. The first round in each part did not provide any information on the previous round and was therefore dropped for the analysis, yielding 16 rounds in each part for a total of 48 rounds.

[4]The three parts were implemented to avoid that data would be rendered meaningless by convergence to the Walrasian outcome, since after convergence occurs, there is no behavioral variance. Payoff table 1: $P(Q) = 150 - Q$, $A = 37.5$, $B = 33.25$, $C = 30$, $D = 18.75$ (or reversed); Payoff table 2: $P(Q) = 175 - Q$, $A = 43.75$, $B = 38.875$, $C = 35$, $D = 21.875$ (or reversed); Payoff table 3: $P(Q) = 200 - Q$, $A = 50$, $B = 44.5$, $C = 40$, $D = 25$ (or reversed).

4.2 Experimental Procedures and Cognitive Load Manipulations

Experiments 1–3 were conducted at the Cologne Laboratory for Economic Research (CLER), University of Cologne, and programmed in z-Tree (Fischbacher, 2007). Participants were recruited using ORSEE (Greiner, 2015), and were students from the University of Cologne excluding those with majors in Psychology, Economics, or Advanced Business Administration. They received a performance-based payment plus a show-up fee of 2.50 Euro.

4.2.1 Experiment 1: High-Demand Load (Between)

In Experiment 1, we ran 6 sessions with 24 participants each for a total of $N = 144$ (87 females; age range 18–39 years, mean 23.2 years). The experiment was conceived as a between-subject manipulation, with 72 subjects in a *Load* treatment and the remaining 72 in a *No Load* treatment (three sessions each). Average earnings, including the show-up fee, were 13.61 Euro and 20.12 Euro under No Load and Load, respectively. Participants in the Load treatment earned more due to the additional earnings in the secondary (cognitive load) task; excluding those (earnings from the primary task, the game, in the Load treatment 14.06 Euro), average earnings were not significantly different across treatments (MWW, $N = 144$, $z = -1.489$, $p = .1365$). A session lasted around 85 and 105 minutes in the No Load and Load treatments, respectively.

In the Load treatment, participants were asked to memorize a seven-digit number which was displayed for 10 seconds before each Cournot oligopoly decision, and recall it after that decision (within 10 seconds). Memorizing a number is a common cognitive load task targeting the phonological loop and has been implemented in a variety of experiments (Roch et al., 2000; Hinson et al., 2002; Morey and Cowan, 2004; Lavie and de Fockert, 2005; Allen et al., 2006; Carpenter et al., 2013; Allred et al., 2016). Correct recall was incentivized with an additional 750 points. As a comparison, participants earned an average of 1200 points per round from the Cournot oligopoly decision. In the No Load treatment, no load was present during the whole experiment.

4.2.2 Experiment 2: High-Demand Load (Within)

Data was collected in two sessions with 28 and 32 participants, respectively, for a total of 60 participants (36 female; age range 18–70 years, mean 26.3 years). Average earnings were 17.67 Euro (ranging from 12.70 to 21.70 Euro including the show-up fee). A session lasted about 105 minutes.

The cognitive load manipulation was the same as in Experiment 1, but was implemented within-subject. In each of the three parts, 8 rounds corresponded to Load and 8 to No Load. The very first round of each part, excluded from the analysis, was also under No Load. Again, correct recall was incentivized with an additional 750 points. Rounds without cognitive load included no memorization task.

4.2.3 Experiment 3: Low-Demand Load (Within)

Data was collected in two sessions of 32 participants each for a total of 64 participants (28 female; age range 18–33 years, mean 24.6 years). Average earnings were 18.45 Euro (ranging from 15.00 to 26.50 Euro, including the show-up fee). A session lasted about 105 minutes.

As in Experiment 2, we implemented two within-subject treatments, *Load* and *No Load*, but relied on a lower-intensity (easier) cognitive load manipulation targeting the phonological loop. In each of the three parts, 8 rounds corresponded to Load and 8 to No Load. The very first of each part, excluded from the analysis, was also under No Load. For rounds with cognitive load, participants were asked to memorize a single-digit number which was displayed for 5 seconds before the Cournot oligopoly screen appeared. During the Cournot oligopoly decision task, the participants heard another single-digit number via headphones which was played at a random time between 1 and 10 seconds. After the Cournot decision was made, participants had to enter the sum of the two numbers in a new screen.[5] The cognitive load task was incentivized and each correct answer earned an additional 750 points. Rounds without cognitive load included no additional secondary task.

4.3 Results: Response Times

To test predictions H1a,b, we computed the individual-level average response times for decisions taken in the No Load and Load treatments, for each of the Experiments 1–3. First, we confirm prediction (H1a) for all three experiments. In Experiment 1 (between), participants in the Load treatment were on average faster (9.43 s) than those in the No Load treatment (13.15 s; Mann-Whitney-Wilcoxon test, MWW, $N = 144$, $z = -4.96$, $p < .001$, $r = -.41$). In Experiment 2 (within), participants took on average 9.89 s for rounds under load and 14.90 s for those without load (Wilcoxon Signed-Rank test, WSR, $N = 60$, $z = -6.59$, $p < .001$, $r = -.85$). In Experiment 3 (within), using the easier cognitive load task, participants took on average 14.34 s under load and 15.22 s without load. This is a smaller but still significant difference (WSR, $N = 64$, $z = -3.11$, $p = .002$, $r = -.39$).

Figure 1 displays the averages of the individual-level average response times for decisions taken in the No Load and Load treatments, for each of the Experiments 1–3. Data is split according to whether the decisions in each round were made under conflict or alignment (that is, whether the imitative choice and the myopic best reply differ or coincide, respectively), as required to test for prediction (H1b).

Indeed, we confirm prediction (H1b) in conflict situations for all three experiments. The predicted relation holds between subjects for Experiment 1 (Load, 9.30 s; No Load treatment, 13.10 s; MWW, $N = 144$, $z = -5.11$, $p < .001$, $r = -.43$), and within

[5] This design makes the manipulation closer to Buckert et al. (2017), who used a concurrent "distraction" task. We thank Ronald Hübner for suggesting this manipulation.

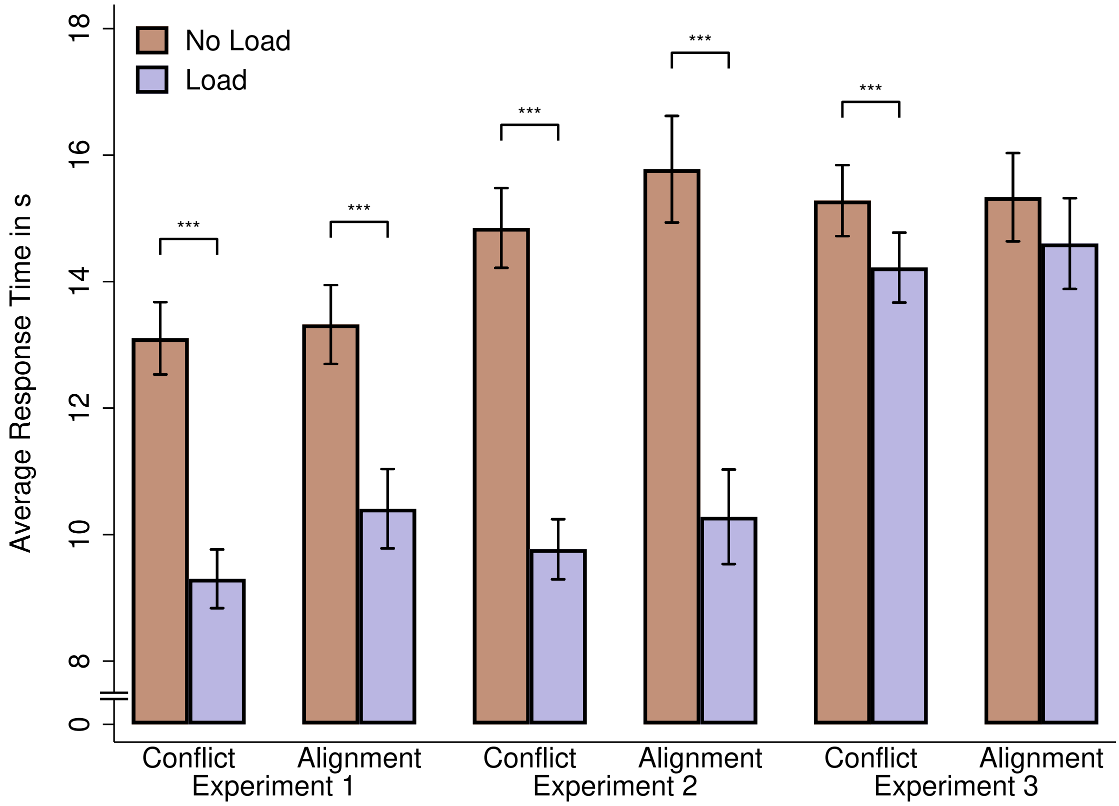

Fig. 1 Response Time Results, Experiments 1–3 (Cournot Markets). Average response times of decisions under load and no load in conflict and alignment. Stars indicate significance levels according to Mann-Whitney-Wilcoxon (Experiment 1) and Wilcoxon Signed-Rank tests (Experiments 2 and 3), * $p < .05$, ** $p < .01$, and *** $p < .001$

subjects for Experiment 2 (Load rounds, 9.77 s; No Load rounds, 14.85 s; WSR, $N = 60$, $z = -6.52$, $p < .001$, $r = -.84$) and Experiment 3 (Load rounds, 14.22 s; No Load rounds, 15.28 s; WSR, $N = 64$, $z = -3.40$, $p < .001$, $r = -.42$). The prediction also holds for alignment situations in Experiment 1 (Load, 10.41; No Load, 13.32 s; MWW, $N = 144$, $z = -3.55$, $p < .001$, $r = -.30$) and Experiment 2 (Load rounds 10.28 s; No Load rounds, 15.78 s; WSR, $N = 57$, $z = -5.14$, $p < .001$, $r = -.68$).[6] In Experiment 3, relying on the easier cognitive load task, participants were also faster on average in Load rounds (14.60 s) compared to No Load rounds (15.33 s), but the difference was not significant (WSR, $N = 63$, $z = -1.28$, $p = .200$, $r = -.16$).

4.4 Results: Behavior

The previous subsection shows that the cognitive load manipulations were implemented successfully in Experiments 1–3. Following the standard logic of cognitive load manipulations, one would expect a shift toward more intuitive decisions, which in this case

[6] The number of observations changes across tests because not all subjects faced decisions in alignment situations.

means more imitative choices. By virtue of Theorem 2, our model would actually support this prediction, but only for decisions under conflict, and only if we accept the strong additional assumption (B2). In our Cournot oligopoly experiments, this assumption states that imitation should be unaffected by cognitive load, which we consider implausible. Imitation can be assumed to be *less* deliberative than myopic best reply, but it is unlikely to be a purely automatic process not relying on any cognitive resources (such as positive reinforcement).

Figure 2 displays the relative frequency of imitative choices in conflict situations for Experiments 1–3, across (between or within) treatments. There were, however, no significant differences in Experiment 1 (Load subjects, 37.49% imitative choices; No Load subjects, 34.97%; MWW, $N = 144$, $z = 0.45$, $p = .652$, $r = .04$) or in Experiment 3 (Load rounds, 30.42%; No Load rounds, 31.22%; WSR, $N = 64$, $z = -0.17$, $p = .862$, $r = -.02$). In Experiment 2, the relative frequency of imitation did increase significantly under cognitive load (Load rounds, 34.96%; No Load rounds, 31.79%; WSR, $N = 60$, $z = 2.05$, $p = .040$, $r = .26$). In summary, results are mixed and do offer only weak or no support for prediction (H2) and assumption (B2).

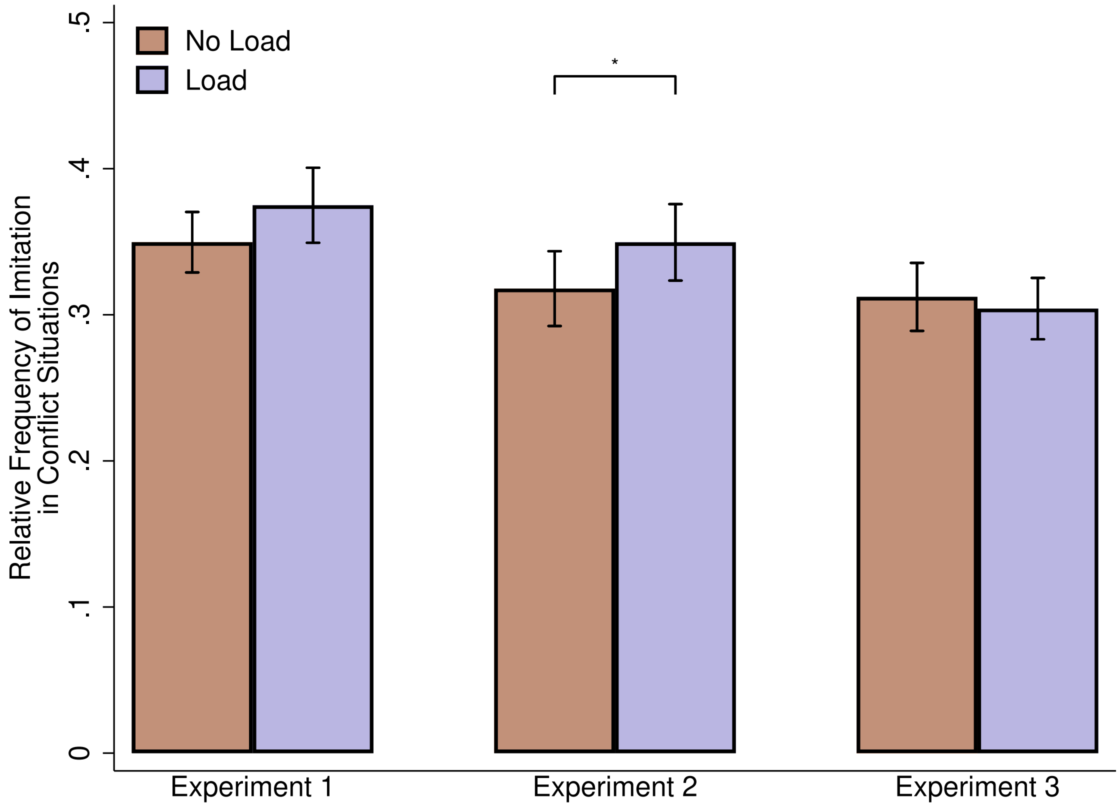

Fig. 2 Behavioral Results, Experiments 1–3 (Cournot Markets). Relative frequency of imitation decisions in conflict situations. MWW (Experiment 1) and WSR tests (Experiments 2, 3), * $p < .05$, ** $p < .01$, and *** $p < .001$

4.5 Discussion (Experiments 1–3)

Cournot oligopoly experiments with a large payoff table deliver an example of economically relevant but relatively complex individual decisions due to the interactive environment which involves other participants. In three separate experiments using both between and within settings and relying on two different cognitive load manipulations, we show that decisions under cognitive load are, as predicted by (H1a,b), faster under cognitive load. The difference in response times remains as expected when disentangling decisions according to whether they were made under conflict or under alignment.

The cognitive load manipulation we use in Experiments 1 and 2 is widely used in the literature (e.g., Roch et al., 2000; Hinson et al., 2002; Carpenter et al., 2013; Allred et al., 2016). Using this manipulation, the effect on response times is relatively large. The effect is much smaller (although still generally significant) in Experiment 3, suggesting that the manipulation we used in this case was indeed weaker. To substantiate this claim, we computed the individual-level difference in average response times between No Load and Load in case of conflict in Experiments 2 and 3 (which both involved within-subject manipulations; we focused on conflict because the basic effect is significant in both experiments in this case). The difference was significantly larger in Experiment 2 (5.08 s) compared to Experiment 3 (1.06 s; MWW test, $N = 124$, $z = 5.98$, $p < .001$, $r = .54$).

In particular, we conclude that our manipulations successfully impaired cognitive resources. In spite of this, actual effects on behavior were obtained only in Experiment 2, yielding weak support to the conventional wisdom that impairing cognitive resources should increase the frequency of the actions (most often) prescribed by (more) intuitive processes. This is, however, compatible with the view that cognitive load might also partially affect the inner workings of more (but not fully) intuitive processes, for in this case assumption (B2) is unwarranted and prediction (H2) does not necessarily follow.

5 Experiments 4–6: Voting Decisions

In this section, we discuss three voting experiments where participants took the role of committee members and voted for different options according to two voting methods. One reason to use voting experiments is that, as we will discuss below, they constitute an example of a complex situation where, even though there are natural candidates for two different behavioral rules, the actual prescriptions do not suffice to distinguish conflict and alignment *ex ante*. However, our results still make a clear prediction (H1a) and the standard logic behind cognitive manipulations still suffices to identify an expected behavioral effect.

In this voting paradigm, each participant was part of a small committee (council of six, including onself) and had to vote between four different proposed alternatives. Among the six members there were three different types of interests groups, each consisting of two members. Each type/interest group may value the alternatives differently and the primary task for the participant was to cast a valid ballot according to the current voting method.

An important objective of a voting method is to elicit and represent the electorate's preferences faithfully. However, theoretical results in social choice theory have shown that any voting method within a wide family is manipulable and creates incentives to vote strategically, i.e., misrepresenting the own actual preferences for Candidate A by voting for Candidate B to avoid getting Candidate C elected (Gibbard, 1973; Satterthwaite, 1975). This is especially true for Plurality Voting, where each voter casts a single vote for his or her most-preferred alternative and the alternative with the most votes wins, a method which forms the basis of most actual electoral methods in use in Western societies. A particular problem is the "wasted vote" effect, where voters refrain from supporting their actually-preferred candidate (e.g., most-preferred Candidate A) or party in the belief that its winning chances are too small, supporting a popular alternative (e.g., Candidate B) instead not because they actually prefer it, but because it is the least-disliked among those likely to win (popular Candidates B and C).

An alternative method which partially escapes manipulability (because it does not belong to the class covered by the results mentioned above) is Approval Voting (Brams and Fishburn, 1978; Alós-Ferrer and Buckenmaier, 2019). In this method, voters can vote for ("approve of") as many alternatives as they see fit, with the winner determined by simple majority of approvals. In particular, Approval Voting escapes the waste vote effect, since approving of a non-favorite option can be accomplished by merely moving the approval threshold without misrepresenting preferences, and, in particular, without disapproving of the favorite option. Under this voting method, the voter can approve of his most-preferred Candidate A, revealing her support, but may also approve of Candidate B, expressing that both candidates are preferred to Candidate C. The voter does not need to choose between revealing her most-preferred Candidate A and strategically voting for the least-disliked Candidate B of the popular alternatives (Candidates B and C). Voting field experiments have provided evidence that election outcomes might greatly differ if Approval Voting were used instead of more-established methods (Laslier and Van der Straeten, 2008; Alós-Ferrer and Granić, 2012, 2015).

In the context of voting, hence, the natural behavioral rules to consider are *sincere voting* vs. *strategic behavior.* Since the latter requires reasoning about the likely behavior of others, it should correspond to a more deliberative mode of thinking. This is also in agreement with the more general view that sincerity is an intuitive reaction, e.g. as compared to dishonest behavior (Cappelen et al., 2013; Fischbacher and Föllmi-Heusi, 2013).

In contrast to the experiments in the previous section, the actual prescriptions of one of the postulated behavioral rules are unclear. This is because there is considerable heterogeneity in strategic behavior (Stahl and Wilson, 1995; Ho et al., 1998), and hence the actual prescriptions in this case would depend on a variety of individual correlates including cognitive capacity. Thus, although in the experiments below it is always possible to determine whether a decision was sincere or not, it is not possible to classify decisions as happening in conflict or alignment. This, however, is no obstacle for our analysis, because prediction (H1a) does not rely on this classification. As for effects on behavior, though, this is an example where conventional wisdom would expect a shift toward more intuitive behavior (in this case, sincere voting) under cognitive load, but actual theoretical results are lacking, since prediction (H2) does hinge on decisions being made under conflict.

The experiments again used different cognitive load manipulations, but were all within-subject. As in the previous section, we first present the common experimental design, then the cognitive load manipulations, and finally the results for response times and voting decisions for all three experiments.

5.1 Shared Experimental Design

For Experiments 4–6, we considered a complex voting decision. The decision task was strictly individual, because no feedback on voting outcomes was provided until the end of the experiment. We relied on the standard design of voting experiments following Forsythe et al. (1993, 1996) (see also Granić, 2017). Specifically, the primary (decision) task was to cast a vote using different voting methods, implemented in separate blocks.

Participants were allocated to groups of six voters each and cast their votes for four possible alternatives, A, B, C, and D. In each group, there were three voter types, with two participants randomly allocated to each type. They were confronted with "societies" represented by payoff profiles which consisted of a payoff outcome for each possible alternative and each type, i.e. a 3×4 payoff table. Votes were cast according to either Plurality Voting or Approval Voting. Participants voted multiple times in two different voting blocks, one per method. The order of methods was counterbalanced across participants.

Under Plurality Voting, each participant voted for exactly one of the alternatives and the alternative with the most votes won. Under Approval Voting, each participant voted for as many alternatives as she approved of and the alternative with the most approvals won. Ties were broken randomly. At the end of the experiment, one voting round was randomly drawn and the winning alternative was determined according to the voting method and the votes of all members of the group.[7]

Experiment 4 used the payoff profiles of Societies 1 and 2 in Table 1, while Experiments 5 and 6 used Societies 3 and 4.[8] The exchange rate was 12 Eurocents per point.

[7] In economics, decisions are typically incentivized. Azrieli et al. (2018) showed under which assumptions paying one decision or paying all decisions is incentive compatible. In this setup, paying one decision is incentive compatible.

[8] The Societies differed in how the alternatives across the voter types may have been perceived. For instance, Society 2 offered an equal-profit alternative (D) for all voter types which could possibly be a focal point. This is of interest for an in-depth analysis of voting behavior within the voting literature, however, not the main focus of this paper and we therefore keep the Society labels neutral.

Table 1 Voter Profiles, Experiments 4–6

Society 1 (Exp. 4)					
Voter	#	A	B	C	D
Type 1	2	60	50	70	80
Type 2	2	70	80	50	60
Type 3	2	70	60	80	50

Society 2 (Exp. 4)					
Voter	#	A	B	C	D
Type 1	2	50	70	80	60
Type 2	2	50	80	70	60
Type 3	2	80	70	50	60

Society 3 (Exp. 5,6)					
Voter	#	A	B	C	D
Type 1	2	60	50	70	80
Type 2	2	70	80	50	60
Type 3	2	70	60	80	50

Society 4 (Exp. 5,6)					
Voter	#	A	B	C	D
Type 1	2	50	60	80	70
Type 2	2	50	80	70	60
Type 3	2	80	70	50	60

Note. Societies 1 and 2 were used in Experiment 4; Societies 3 and 4 were used in Experiments 5–6.

In each experiment, each payoff profiles was used four times per voting method, but the payoffs were jittered using small random perturbations which did not alter the ordinal relation among outcomes. Furthermore, the names of the alternatives were shuffled and the rows in the payoff profile rearranged to avoid demand for consistency. In Experiment 4, each voter's (actual) type also changed across voting decisions, while in Experiments 5 and 6 it was fixed.

5.2 Experimental Procedures and Cognitive Load Manipulations

Procedures and recruitment for Experiments 4–6 were as those for Experiments 1–3, including software platforms. Participants were students from the University of Cologne excluding those with majors in Psychology, and those who had participated in previous voting experiments. They received a performance-based payment of 4 Euro (as the lab-mandated fee had increased with respect to Experiments 1–3).

5.2.1 Experiment 4: High-Demand Load (Within)

In Experiment 4, we ran 2 sessions with 30 participants each for a total of $N = 60$ (38 females; age range 18–32 years, mean 23.1 years). Average earnings were 18.29 Euro (ranging from 12.00 to 22.20 Euro including the show-up fee[9]). A session lasted around 75 minutes.

The cognitive load manipulation was the same as in Experiment 2, and also implemented within subjects. The payoff for correct recall was 40 points (one round was randomly selected for payment). Table 2(top) details the order of payoff profiles and treatments within each block of voting decisions. Payoff profiles were jittered independently each voting round.

[9]Due to a programming error, each participant received 12 extra points at the end of the experiment.

Table 2 Sequence of Voting Rounds

Round	1	2	3	4	5	6	7	8
Load	No	Yes	No	Yes	Yes	No	No	Yes
Society	1	2	2	1	2	1	2	1

Round	1	2	3	4	5	6	7	8	9	10
Load	No	Yes	Yes	No	No	No	Yes	No	No	Yes
Society	3	4	3	4	Filler	Filler	3	4	3	4

Note. Order of Cognitive Load Rounds and Payoff Profiles Within a Voting Block. Top: Experiment 4; Bottom: Experiments 5–6.

5.2.2 Experiment 5: High-Demand Load (Within)

In Experiment 5, we ran 4 sessions with 30 participants each for a total of $N = 120$ (68 females; age range 18–30 years, mean 23.3 years). Average earnings were 15.53 Euro (ranging from 9.60 to 18.80 Euro including the show-up fee). A session lasted around 75 minutes.

The cognitive load manipulation was as in Experiments 2 and 4, and also implemented within subjects. The payoff for correct recall was reduced to 30 points (one round was randomly selected for payment). Table 2 (bottom) details the order of payoff profiles and treatments within each block of voting decisions. There were two filler rounds with additional (different) Society payoff profiles without load. Payoff profiles for Societies 3 and 4 were jittered twice, so that the exact same profiles were presented after and before the filler tasks (and each profile was faced with and without load), but participants saw four different profiles before the filler tasks, and four different profiles after them.

5.2.3 Experiment 6: Taxing the Visuospatial Sketchpad

In Experiment 6, we ran 4 sessions with 30 participants each for a total of $N = 120$ (74 females; age range 17–58 years, mean 23.1 years). Average earnings were 15.40 Euro (ranging from 9.20 to 18.80 Euro including the show-up fee). A session lasted around 65 minutes.

The voting task and voting block design was identical to Experiment 5. The cognitive load task, however, substantially differed from all previous experiments. We switched to another subsystem of working memory, the visuospatial sketchpad. The task we used required memorizing a visual pattern which cannot be easily (and silently) articulated as a number sequence as in the previous experiments. This task is widely used (Bethell-Fox and Shepard, 1988; Miyake et al., 2001; De Neys, 2006; Franssens and De Neys, 2009; Trémolière et al., 2012; Johnson et al., 2016). The visual pattern consisted of a dot matrix displayed as a 3×3 grid containing 4 black and 5 white dots (see examples in

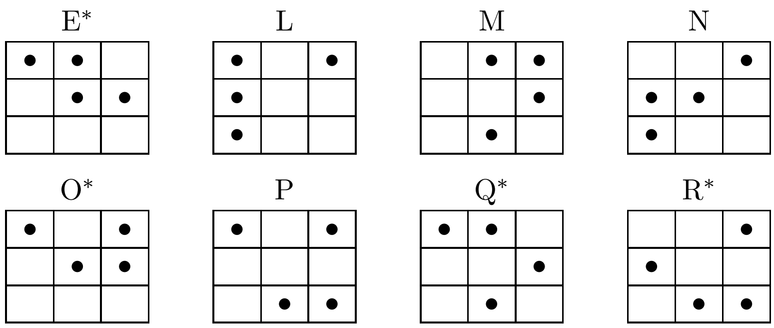

Fig. 3 Visual Load Grids, Experiment 6

Table 3).[10] The matrix was presented for 1 second and had to be recalled (by activating black dots in an empty grid) after the voting decision. The rest of the implementation details (including payment) were as in Experiment 5.

5.3 Results: Response Times

Since we cannot disentangle decisions in conflict and in alignment, we compute individual average response times differentiating decisions under Load and No Load. Prediction (H1a) then states that, if cognitive load has been successfully induced, decisions under Load must be significantly faster. Figure 4 displays the average of the individual average response times conditional on treatment, for each of the Experiments 4–6. Data is split according to voting method (PV=Plurality Voting, AV=Approval Voting).

We confirm prediction (H1a) for Experiments 4 and 5 under both voting methods. In Experiment 4, decisions under Load were on average faster than those under No Load both for Plurality Voting (Load, 15.32 s; No Load, 21.77 s; WSR, $N = 60$, $z = -5.68$, $p < .001$, $r = -.73$) and for Approval Voting (Load, 15.25 s; No Load, 22.01 s; WSR, $N = 60$, $z = -5.90$, $p < .001$, $r = -.76$). The same holds for Experiment 5 (Plurality Voting: Load, 18.25 s; No Load, 23.18 s; WSR, $N = 120$, $z = -6.47$, $p < .001$, $r = -.59$; Approval Voting: Load, 19.09 s; No Load, 24.49 s; WSR, $N = 120$, $z = -6.82$, $p < .001$, $r = -.62$).

In Experiment 6, prediction (H1a) was also confirmed under Approval Voting (Load, 21.09 s; No Load, 22.92 s; WSR, $N = 120$, $z = -3.24$, $p = .001$, $r = -.30$), although the difference was of smaller magnitude. There was, however, no significant effect for Plurality Voting (Load, 21.57 s; No Load 21.68 s; WSR, $N = 120$, $z = -.72$, $p = .471$, $r = -.07$).

5.4 Results: Behavior

The previous subsection shows that the cognitive load manipulations were implemented successfully in Experiments 4–6. In this case, the received logic behind cognitive load

[10] The patterns were rotated versions of the following base patterns taken from Bethell-Fox and Shepard (1988): $E^*, L, M, N, O^*, P, Q^*, R^*$.

manipulations would lead us to expect a shift toward more sincere voting, reflecting the more deliberative nature of strategic behavior. However, our Theorem 2 would only support this prediction for decisions under conflict, and only if we accept the additional assumption (B2).

Sincere voting under Plurality Voting corresponds to voting for the most-preferred alternative. Under Approval Voting, a ballot is sincere if it includes all alternatives strictly preferred to any alternative in the ballot. Figure 5 displays the relative frequency of sincere votes for Experiments 4–6, across treatments and voting methods.

We find significant effects in Experiment 4. Under Plurality Voting, in this experiment, 64.17% of the decisions under Load were sincere, compared to 55.42% sincere votes under No Load (WSR, $N = 60$, $z = -2.26$, $p = .024$, $r = -.30$). There was a tendency (which missed significance) in the expected direction also for Approval Voting (Load, 87.50%; No Load, 82.92%; WSR, $N = 60$, $z = -1.68$, $p = .092$, $r = -.22$).

In contrast, there were no significant differences for either method, neither in Experiment 5 (Plurality Voting: Load, 60.00%; No Load, 57.71%; WSR, $N = 120$, $z = -1.27$, $p = .206$, $r = -.12$; Approval Voting: Load, 89.17%; No Load, 88.54%; WSR, $N = 120$, $z = -0.51$, $p = .609$, $r = -.05$) nor in Experiment 6 (Plurality Voting: Load, 58.54%;

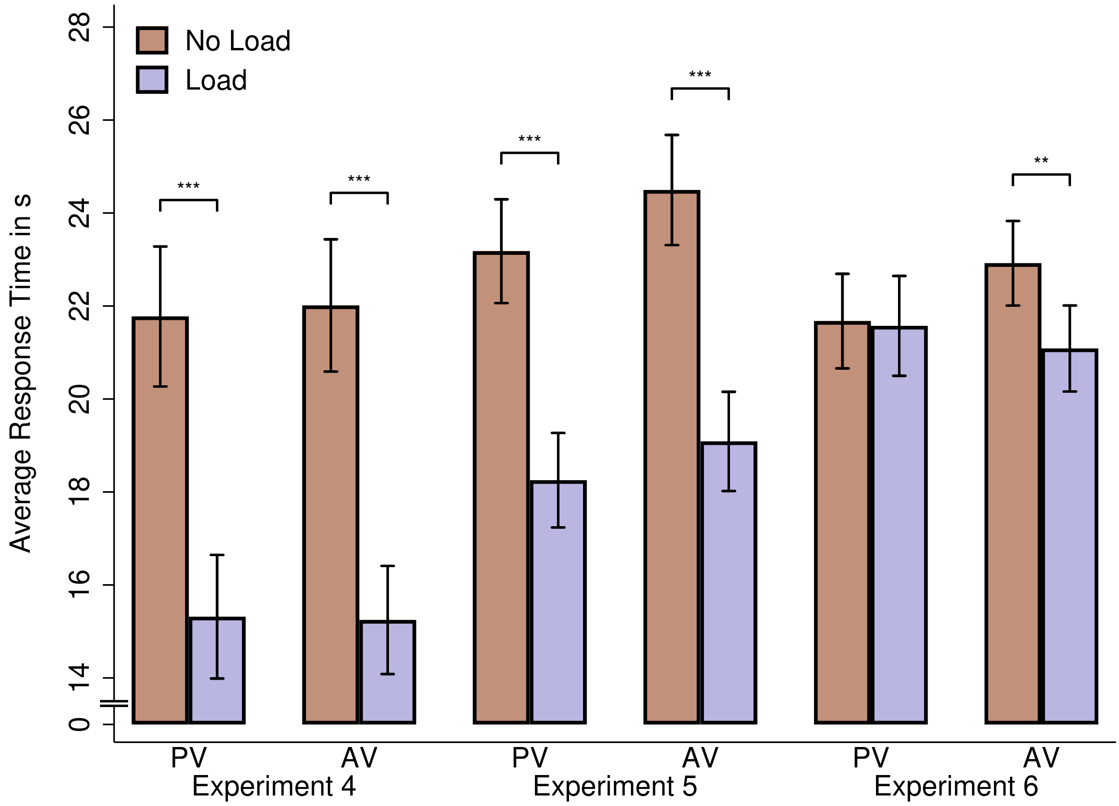

Fig. 4 Response Time Results, Experiments 4–6 (Voting). Average response times of voting decisions under load and no load in Plurality Voting (PV) and Approval Voting (AV). WSR test, * $p < .05$, ** $p < .01$, and *** $p < .001$

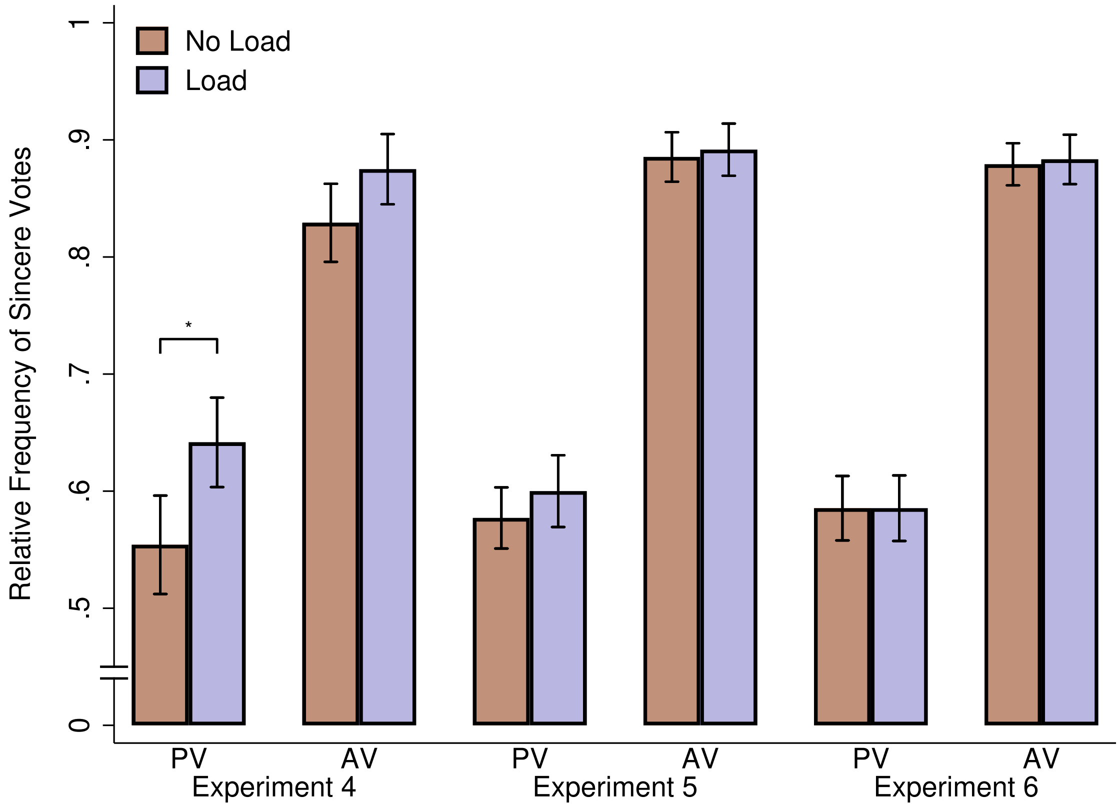

Fig. 5 Behavioral Results, Experiments 4–6 (Voting). Relative frequency of sincere votes. WSR, * $p < .05$, ** $p < .01$, and *** $p < .001$

No Load, 58.54%; WSR, $N = 120$, $z = 0.15$, $p = .879$, $r = .01$; Approval Voting: Load, 88.33%; No Load, 87.92%; WSR, $N = 120$, $z = -0.71$, $p = .478$, $r = -.06$). Thus, behavioral results are again mixed and, in view of our model, suggest that the strong assumption (B2) is unwarranted in this case.

5.5 Discussion (Experiments 4–6)

Voting experiments involving even small committees (six members in our case) involve complex, strategic decisions which interact with the voting method in place. In three separate experiments using two different voting methods (Plurality and Approval Voting) and two different cognitive load manipulations (phonological and visuospatial load), we show that decisions under cognitive load are, as predicted by (H1a), faster under cognitive load. The experiments are an example of a setting where, even though there exist clear candidates for the involved intuitive and deliberative processes, individual heterogeneity (i.e. strong variations of these processes within and between individuals) precludes identifying the prescriptions of the latter and hence differentiating conflict and alignment. However, Theorem 1 of our model still delivers a prediction, which we readily find in the data.

Experiment 6 relied on a cognitive load manipulation targeting the visuospatial sketchpad, instead of the phonological loop as most of our experiments. Thus, it is difficult to compare the strength of this manipulation with those of other ones from an *ex ante* point of view. However, our results show that the predicted difference in response times obtains only for one of the voting methods, and is of smaller magnitude than that found in other experiments, suggesting that the manipulation of visual cognitive load indeed differs from those targeting the phonological loop, and is most likely weaker. To substantiate this observation, we computed the individual-level differences in average response times between No Load and Load in Approval Voting in Experiments 5 and 6 (we focused on AV because the basic effect is significant in both experiments for this method). The difference was larger in Experiment 5 (5.41 s) than in Experiment 6 (1.83 s; MWW test, $N = 240$, $z = 3.78$, $p < .001$, $r = .24$). This is of independent interest, since the particular manipulation used in Experiment 6 is frequently used in the psychological literature (e.g., Miyake et al., 2001; De Neys, 2006; Franssens and De Neys, 2009; Trémolière et al., 2012; Johnson et al., 2016).

We conclude that our manipulations also successfully impaired cognitive resources in our voting experiments. However, effects on behavior reflecting conventional expectations were obtained only in Experiment 4. As in Experiments 1–3, the overall picture is compatible with the view that cognitive load might also partially affect the more-intuitive processes at work in this paradigm.

6 Experiment 7: Bayesian Updating

In this section, we discuss an experiment which differs from the previous ones along several dimensions. First, we focus on a task which, although arising from the economics literature (Charness and Levin, 2005; Achtziger and Alós-Ferrer, 2014), involves much shorter response times (with averages between 1 and 3 s) than the ones in Experiments 1–6 and hence might be closer to experiments in cognitive psychology in this sense. Second, the task is completely non-strategic, in the sense that it does not involve thinking about other agents' decisions and their potential consequences for oneself, but it is still relatively complex (as reflected by high error rates). Third, the experiment includes three treatments, a control condition and two cognitive load manipulations, and one of the latter is particularly taxing compared to previous ones (a "central executive" load).

This is a belief-updating task using an urns-and-balls paradigm as typical of the judgment and decision making literature (e.g., Kahneman and Tversky, 1972; Grether, 1980, 1992), developed by Charness and Levin (2005) to study the possible conflict between Bayesian updating of beliefs and a simple win-stay, lose-shift reinforcement heuristic. This paradigm is interesting because participants can update their beliefs in a normative way on the basis of received information, but the latter carries a win-loss frame, as is typical in many economic applications (project success vs. failure, firm's profits vs. losses, stocks going up or down, etc.). This frame cues basic reinforcement

State (Prob)	Left Urn	Right Urn
First (1/2)	●●●●○○	●●●●●●
Second (1/2)	●●○○○○	○○○○○○

Fig. 6 Schematic Representation of the Primary Task, Experiment 7

behavior, giving rise to a focus on past performance and well-known behavioral anomalies as *outcome bias* (e.g. Baron and Hershey, 1988). Charness and Levin (2005) showed that error rates in this paradigm are particularly high, and Achtziger and Alós-Ferrer (2014) used response times to show that the high error rates originate on reinforcement behavior. Achtziger et al. (2015) investigated the neural foundations of reinforcement behavior in this paradigm, and a number of other works have relied on it for further research (Charness et al., 2007; Hügelschäfer and Achtziger, 2017; Alós-Ferrer et al., 2017; Li et al., 2019; Alós-Ferrer et al., 2021).

In Experiment 7, thus, the behavioral rules we consider are a deliberative one implementing optimal decisions following Bayesian updating of beliefs (or simply "Bayesian updating" for short), and a more intuitive win-stay, lose-shift rule implementing a reinforcement-based heuristic. This experiment is an example of a paradigmatic comparison between deliberative and intuitive/automatic processes. On the one hand, it is well-known that human beings have notorious difficulties updating beliefs in a normative way (e.g., Kahneman and Tversky, 1972; Grether, 1980, among many others), and hence behavioral rules supporting normative behavior in this setting can be safely considered deliberative. On the other hand, evidence from neuroscience shows that reinforcement learning bears all the markers of automaticity and is associated with very fast and often-unconscious brain responses (e.g., Schultz, 1998; Holroyd and Coles, 2002).

6.1 Experimental Design

The primary task was neutrally framed and was as follows. There were two urns (left and right), each containing 6 balls, which could be black or white. Each participant completed 60 independent trials. In each trial, a state of the world (first or second) was realized, with probability 1/2 for each state (see Figure 6). In the first state of the world, the left urn consisted of 4 black and 2 white balls and the right urn of 6 black balls. In the second state of the world, the left urn consisted of 2 black and 4 white balls and the right urn of 6 white balls. All this information (but not the actually-realized state of the world) was known by participants.

In each trial, participants decided whether the left or the right urn should be used to extract a single ball, and received a payment of 18 Eurocents if and only if the ball was of a pre-specified color (say, black).[11] The extracted ball was replaced into the original

[11] The actual colors were counterbalanced. Following Charness and Levin (2005) and Achtziger and Alós-Ferrer (2014), in the first 30 trials the first decision was forced, following an alternating left-right pattern.

urn, and participants had to choose an urn again, with a new ball being extracted and resulting in payment as in the first extraction. The focus of the analysis is on this second decision within each trial, as a rational decision maker should use Bayes' rule to update his or her beliefs on the state of the world on the basis of the feedback (black or white ball) from the first decision, but a reinforcer could use a simple "win-stay, lose-shift" heuristic and stick to the previous choice if and only if it was successful.

The composition of the urns was such that both behavioral rules (Bayesian updating and reinforcement) were always in conflict if the first extraction of a ball was from the left urn (i.e., Bayesian updating prescribes "win-shift, lose-stay"), and always in alignment if that first extraction of a ball was from the right urn (as the composition of the urns in that case revealed the state of the world); see Charness and Levin (2005) or Achtziger and Alós-Ferrer (2014) for details.

6.2 Experimental Procedures and Cognitive Load Manipulations

The experiment was carried out at the Social Psychology laboratory at the University of Konstanz (Germany), with each participant being measured individually and independently. Participants were 60 university students (21 female), randomly allocated to three different treatments. They earned 11.62 Euro on average (the cognitive load manipulations were not incentivized) and a session lasted around one hour.

In the *No Load* treatment, participants were not placed under any load. In the *Phonological Load* treatment, participants completed the primary task while repeating the word "and" (German: "und") every 1.5 seconds, following the rhythm given by a physical metronome placed on the table. This manipulation is known to specifically block the phonological loop, which should lead to quick information decay (Baddeley, 1986; Gathercole and Baddeley, 1993) similarly to memorizing a long sequence of digits. In the *Central Executive Load* treatment, participants completed the primary task while naming random numbers (from zero to nine) aloud at the rhythm of the physical metronome. This is a rather-strong manipulation which is known to seriously impair central executive functions and, in addition, tax working memory capacity (e.g. attention) to a strong extent (Baddeley, 1966).

In all cases, participants received careful instructions on both the decision task and the cognitive load task. They practiced the load task in the presence of the experimenter and were instructed that successfully conducting this secondary task was a precondition for payment in the primary task. Their speech during the task was recorded and checked to make sure that they complied with the manipulation (no participants neglected the load task; however, recordings failed for two participants). They also went through five practice trials of the primary task under load.

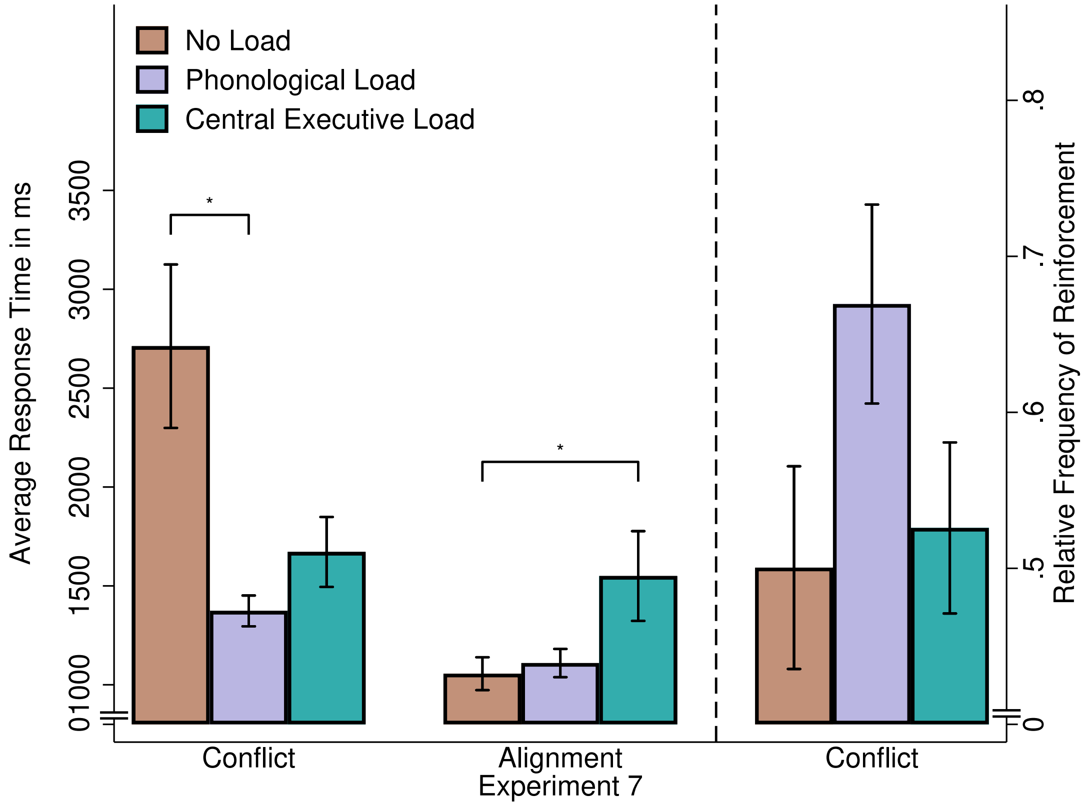

Fig. 7 Response Time and Behavioral Results, Experiment 7. Average response time in conflict and alignment situations (left-hand side) and relative frequency of reinforcement decisions in conflict situations (right-hand side). MWW test, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

6.3 Response Time Results

The left-hand side of Figure 7 displays the average (of individual average) response times of the second draw in the No Load, Phonological Load, and Central Executive Load treatments, conditional on conflict and alignment. The average response times of decisions in case of conflict were $2,712$ ms in the No Load treatment, $1,374$ ms under Phonological Load, and $1,672$ ms in the Central Executive Load treatment. Confirming (H1b), the decrease in response times under load was significant according to Mann-Whitney-Wilcoxon tests, adjusted for multiple comparisons according to the Holm-Bonferroni method (Phonological Load vs. No Load, $N = 40$, $z = -2.62$, $p = .017$, $r = -.41$; Central Executive Load vs. No Load, $N = 40$, $z = -1.89$, $p = .058$, $r = -.30$). The average response times in alignment were $1,056$ ms, $1,110$ ms, and $1,550$ ms under No Load, Phonological Load, and Central Executive Load, respectively. The difference between Phonological Load and No Load was not significant (MWW, $N = 40$, $z = 0.97$, $p = .330$, $r = .15$), and the difference between Central Executive Load and No Load was significant in the opposite direction, that is, decisions in alignment under Central Executive Load were slower (MWW, $N = 40$, $z = 2.25$, $p = .0495$, $r = .35$).

6.4 Behavioral Results

The right-hand side of Figure 7 displays the relative frequency of reinforcement ("win-stay, lose-shift") decisions in the three treatments in conflict situations. The frequencies were 50.04% in the No Load treatment, 66.94% in the Phonological Load treatment, and 52.59% in the Central Executive Load treatment. The increase in the relative frequency of reinforcement under Phonological Load compared to No Load was in the conventionally-expected direction, but missed significance (MWW, $N = 40$, $z = 1.92$, $p = .109$, $r = .30$). There was no significant difference between Central Executive Load and No Load (MWW, $N = 40$, $z = 0.47$, $p = .636$, $r = .07$).

6.5 Discussion (Experiment 7)

Experiment 7 involved a complex decision task for which, however, response times are usually much shorter than in our previous experiments. The predicted effect of cognitive load on response times is readily found for two different cognitive load treatments, but only in case of conflict. In case of alignment, response times are particularly fast and the effects are either negligible or go in the opposite direction, reflecting the more mechanical aspects of having to perform an additional task during the primary one, e.g. those involved in perception and motor implementation. This serves as a reminder of the fact that the domain of application of the effects we discuss is limited to relatively complex tasks where response times are large enough for the differences between processes to be dominant relative to more mechanical effects. This is likely to include most tasks in economics, but few in more classical, psychology ones, as for instance the Stroop task (Stroop, 1935) or the lexical decision task (Meyer and Schvaneveldt, 1971).

Theorem 2 predicts an effect of cognitive load on behavior for decisions in case of conflict. In this case, we do obtain a clear, significant difference in response times (which is also of a large magnitude in relative terms) confirming that cognitive load was successfully induced. The expected effects on behavior narrowly miss significance for Phonological Load, and would have been significant in the absence of a statistical correction due to the presence of a third treatment. This is consistent with the view that reinforcement-based processes are highly automatic, and hence assumption (B2), on which Theorem 2 rests, might be warranted in this case. However, the results are absent for Central Executive Load, which suggests that strong-enough load manipulations have the potential to alter the characteristics of even this kind of processes, with the result that the conventionally-expected effects on behavior do not obtain.

7 General Discussion

Cognitive load is firmly established in psychology as a causal manipulation to study reliance on more intuitive or more deliberative decision processes. As interest on the role of intuition in decision making spread to economics, researchers started relying on this manipulation with the expectation that the balance between intuition and deliberation would be shifted toward the former under load, hence revealing fundamental components of economic preferences. However, the literature in economics can be described as an accumulation of mixed results, with some studies finding the expected shifts in behavior (Milinski and Wedekind, 1998; Carpenter et al., 2013; Duffy and Smith, 2014; Schulz et al., 2014), and others finding no effects (Cappelletti et al., 2011; Cornelissen et al., 2011; Allred et al., 2016; Hauge et al., 2016). A particular problem is that, in the absence of behavioral effects as predicted, it is not possible to say whether the shift toward intuition was not as expected, or rather the cognitive load manipulation was simply unsuccessful.

We offer an explanation of the mixed results in the literature and a possible avenue for improvement. The branches of psychology which have found cognitive load to be a useful tool typically rely on simple, stylized tasks where the intuitive processes involved are quintessentially automatic, in particular relying on very few or no cognitive resources (e.g., the Stroop task or the lexical decision task). At the same time, taxing cognitive resources in such simple tasks will often mechanically (and unsurprisingly) produce slightly longer response times (e.g., due to interference through perception and word meaning in the Stroop task) as decision makers conduct additional cognitive operations during a primary task.

None of this observations apply to the tasks typical of economics. In this field, tasks are generally complex, and associated with relatively long response times. This has several consequences. The first is that the differences between more intuitive and more deliberative processes might be generally larger. In terms of response times, there is more room for the differences to become noticeable. One of the fundamental characteristics of more intuitive processes is that they are faster on average than more deliberative ones. Thus, if cognitive load shifts the balance toward more intuitive processes, it must also reduce observable response times. This is the content of our Theorem 1, which offers a straightforward manipulation check for cognitive load: response times must be shorter under (successfully-induced) load than in its absence, at least in complex tasks (where decisions often take more than one second). Somewhat paradoxically, this effect is unlikely to occur in the classical domains applying cognitive load, as response times are too short (i.e., in most cases definitely below one second) and leave little room for the differences between processes to offset mechanical effects (as for instance, very basic perceptual processes).

The second consequence of the higher complexity associated with economic tasks is that what economists typically consider "intuitive" will generally correspond to behavioral rules and decision processes with at least some cognitive components. Those rules (e.g. imitation) are likely to be "more automatic than" their deliberative alternatives, but unlikely to be "purely" automatic (consuming almost no cognitive resources). As a consequence, those processes will also be affected, possibly in complex ways, by the reduction in the availability of cognitive resources accruing to cognitive load manipulations.

Our Theorem 2 shows formally that the conventional wisdom that load induces more intuitive behavior does obtain, but rests on the additional assumption that intuitive processes remain unaffected by load. The latter is likely to hold in psychological domains of application where intuition corresponds to highly-automatic, stimulus-response processes, but is also likely not to hold for at least part of the tasks which are of interest to economists, as for instance the Ultimatum game, Cournot oligopoly markets, belief-updating, and voting.

In a series of experiments (total $N = 628$), we have shown that different cognitive load manipulations significantly reduced response times in several complex, economic decision tasks. They include very different paradigms: behavior in Cournot oligopolies, voting in committees under different methods, and belief-updating tasks. These observations confirm the prediction of Theorem 1 of our model, and suggest that our response-time test can be used as a manipulation check for cognitive load whenever a task exhibits a certain degree of complexity, specifically in complex decision tasks where decisions are typically much longer than in most of the cognitive tasks investigated under cognitive load in psychology. Importantly, this test is independent of whether or not behavioral effects are found as predicted, and hence allows to disentangle studies where cognitive load was not successfully induced from those where the manipulation did work, but the effect of a shift in the nature of decision processes was not as expected (e.g. Cappelletti et al., 2011; Cornelissen et al., 2011; Allred et al., 2016; Hauge et al., 2016).

In our experiments, and even though we do know that our manipulations were successfully induced, we find partial or no evidence for the conventional prediction that cognitive load should result in more intuitive choices (more imitation, more sincere choices, or more reinforcement-based decisions). We conclude that the additional assumption that the more-intuitive processes involved in the decisions we study are unaffected by load might be unwarranted.

As commented above, it is not surprising that previous work in psychology has not reported a systematic shift in response times as the one we predict and find in our experiments, since we target different kind of tasks from the ones typically studied in (cognitive) psychology. However, only a handful of studies have used cognitive load on relatively complex tasks as the ones reported here *and* reported response times. Those works, however, did not recognize response times as a possible manipulation check.

For instance, Whitney et al. (2008) analyzed the impact of cognitive load (memorizing a five-letter string and recalling a specific letter) on framing effects in decisions under risk (choosing between a gamble and a sure outcome). They report that response times decreased significantly from $2,950$ ms without load to $2,796$ ms with this phonological-loop load. Gerhardt et al. (2016) investigated risk attitudes in a lottery-choice experiment with cognitive load, employing a visuospatial-sketchpad load manipulation (memorizing a dot pattern). They reported that response times decreased significantly from $3,835$ ms without load to $3,449$ ms with load. The authors of both works speculate that participants might have tried to speed up their decisions in order to maintain accuracy in the cognitive load task. Note that Whitney et al. (2008) additionally commented that faster decisions under load were consistent with the notion that decisions relied rather on the intuitive than deliberative system. The main focus of both works was not on the response times effects of cognitive load, and they did not further investigate these findings. We offer a simple explanation for their response times findings according to our model: the manipulations in those papers successfully shifted the balance toward more intuitive processes, which are associated with shorter response times, hence bringing overall observed response times down. Interestingly, both papers did find behavioral effects of cognitive load (less gambling and lower risk aversion, respectively), suggesting that assumption (B2) might be justified in their settings.

One might speculate that the additional incentives provided in our cognitive load manipulations might somehow have induced participants to consciously speed up their decisions. This is unlikely, since, for example, we also observe the effect in Experiment 7, where the cognitive load manipulations (repeating the word "and" or generating random numbers aloud) were not incentivized. Also, Duffy et al. (2016) and Duffy et al. (2020) conducted two different experiments contrasting high cognitive load (remembering 6-digit sequences) with low load (instead of no load; remembering 1-digit numbers), *both* of which were incentivized. They also found that high load resulted in faster decisions (in Duffy et al., 2020, 10.081 s under low load vs. 9.586 s under high load), although the effect was unexpected in those studies.

In several of our experiments, the effect of cognitive load on response times is of a large magnitude in relative terms (Experiments 1, 2, 4, 5, and 7 in case of conflict). In Experiment 3, the cognitive load effect is only significant in case of conflict, and its magnitude is substantially smaller than in Experiments 1–2, which used the same primary task (i.e. Cournot oligopolies). The difference is that Experiment 3 used a different load manipulation (adding up a previously-read single-digit number with another, just-heard single digit). In Experiment 6, the effect is only significant for one of the voting methods (i.e., Approval Voting), and again its magnitude is substantially smaller than in Experiments 4–5, which used the same primary task. Again, the difference is that Experiment 6 used a different cognitive load manipulation (remembering a dot pattern). This suggests that the difference in response times, which we have proposed here as a test, might potentially be used to develop a metric of the comparative strength of different cognitive load manipulations.

Related to this, Experiment 7 offers an additional, potentially-interesting insight. In this experiment, a manipulation targeting the phonological loop produces the predicted effects on response times in case of conflict, and also (although significance is narrowly missed after corrections for multiple testing) the expected increase in intuitive, reinforcement-based choices. However, the primary task involves much shorter response times than other experiments, especially in case of alignment. In the latter, we indeed do not observe any effect on response times, possibly suggesting that the task is close to the boundary of the domain of applicability of Theorem 1. In the same experiment, we also employed a particularly strong manipulation focused on central executive functions, which again yielded a reduction of response times, as predicted, but only in case of conflict. However, the effects of this stronger manipulation on behavior were markedly weaker (than those of phonological load). We argue that this is *not* paradoxical. The intuitive process we focus on in Experiment 7, reinforcement, is relatively automatic, but still rests on cognitive functions (associating success to decisions). A manipulation which does not tax away cognitive resources inordinately will affect reinforcement to a small extent, or not at all. A much stronger manipulation, in contrast, might affect both the more deliberative and the reinforcement process, invalidating the necessary assumptions behind the predicted behavioral effect. In particular, under central executive load, decisions in the binary main task approach 50% for each option, suggesting random behavior.

To summarize, we want to point out problems faced by interdisciplinary research and try to offer a solution when importing methods from one discipline to another. Researchers might be justifiably interested in using cognitive load, but the effects of this manipulation might differ from those expected in view of traditional psychological wisdom, due to the complexity of the decision tasks. The very first conclusion of our analysis is that researchers interested in cognitive load have a new tool at their disposal, allowing them to determine when a cognitive load manipulation has successfully induced a shift in the nature of decision processes employed by experimental participants. At the same time, we warn that researchers should be aware of the fact that conventional wisdom on the behavioral effects of cognitive load rests on additional assumptions on just how automatic the postulated intuitive processes are. Using cognitive load to causally test the role of certain processes in decision making requires a careful, prior analysis of the actual cognitive characteristics of those processes. If the cognitive difference between the postulated more deliberative and more intuitive processes is small or unclear, it is unwarranted to predict any behavioral effects. If the research question involves heuristics or processes of a clearly-automatic nature, or there are objective reasons to expect large differences (in cognitive terms) between the processes at work, the researcher will be fully justified to invoke our Theorem 2 and expect a shift toward more intuitive behavior. In this case, in addition, our Theorem 1 will provide the researcher with a test to ensure that possible null effects are not due to a failure in the manipulation.

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SUPPLEMENTAL MATERIAL
(For Online Publication Only)
Cognitive Load in Economic Decisions

Carlos Alós-Ferrer, Alexander Ritschel, and Anja Achtziger

Supplemental Material – Translated Instructions

This document collects the translated instructions of Experiments 1–7. For a better overview, we separate the instructions of the cognitive load manipulations from those of the experimental tasks.

A Cognitive Load Tasks

A.1 Remembering a Numerical Sequence

[Experiment 1 (Cournot):] Every round, you have the opportunity to earn additional points.

[Experiment 2 (Cournot):] In 8 randomly-selected rounds in each part (out of 17 rounds), you have the opportunity to earn additional points.

[Experiments 4–5 (Voting):] In some rounds, you have the opportunity to earn additional ECU. This will be indicated at the beginning of a round.

[All:] To earn these points/ECU, you have to **memorize** a number that you will see before entering the decision phase. The number consists of **7 digits** and will be displayed for 10 seconds on the screen (see Figure A.1). Then the decision phase starts.

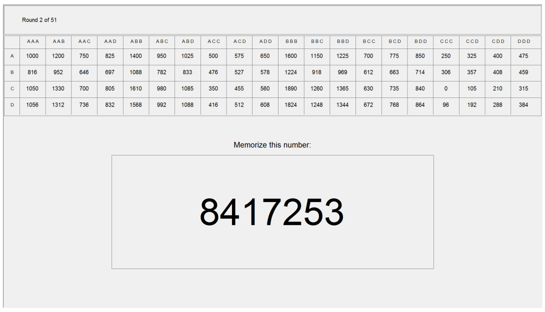


Fig. A.1 Memorizing a 7-digit Number

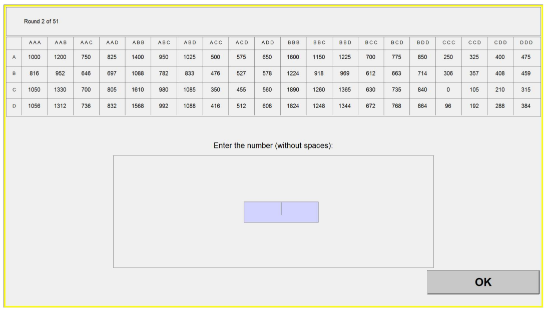


Fig. A.2 Recalling the 7-digit Number

Note. Example screenshots taken from Cournot Oligopoly experiments. The Voting experiments only displayed the load task (without payoff table).

[All:] After the decision phase you have to enter the complete number, that is, all digits and in the correct order (see Figure A.2).

[Experiments 1–2 (Cournot):] If you **correctly** enter the number, you will earn **750** points in addition to the points earned in the decision phase.

[Experiments 4–5 (Voting):] If you **correctly** enter the number, you may earn **30** ECU in addition to the points earned in the decision phase.

[All:] You have to enter the number (without spaces) and click "OK" within 10 seconds, otherwise your answer will be automatically counted as wrong. For a wrong input, you will not receive any points/ECU.

[Experiments 1–2 (Cournot):] The additional points will be added to your points from the decision phase at the end of the experiment.

[Experiments 4–5 (Voting):] At the end of the experiment one round with the additional task will be randomly selected. If you entered the correct number sequence for this round, you will earn 30 ECU.

A.2 Auditory Load

In some rounds, you have the opportunity to earn additional points. This will be indicated at the beginning of a round.

To earn these points you have to add up two digits. The first digit (1-9) will be displayed **before the decision phase** for 5 seconds on the screen (see Figure A.3). Then the decision phase starts. During the decision phase you will **hear** another digit (1-9) after a varying amount of time.

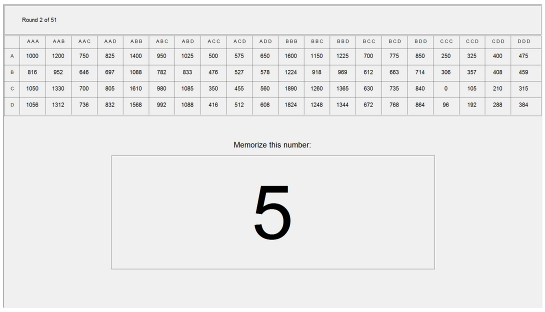


Fig. A.3 Memorizing a Single Digit

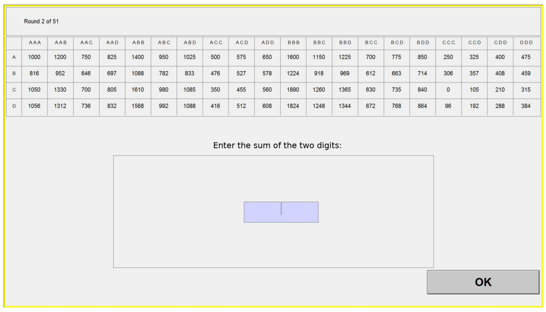


Fig. A.4 Input of the Sum (memorized + heard)

After the decision phase you have to add up the two digits (the digit you memorized before the decision phase and the digit you heard during the decision phase) and enter the sum (see Figure A.4). If you **correctly** enter the number, you will earn **750** points in addition to the points earned in the decision phase .

You have to enter the number (without spaces) and click "OK" within 10 seconds, otherwise your answer will be automatically counted as wrong. For a wrong input, you will not receive any points.

The additional points will be added to your points from the decision phase at the end of the experiment.

A.3 Remembering a Visual Pattern

In some rounds you have the opportunity to earn additional points. This will be indicated at the beginning of a round. To earn these points you have to **memorize** a pattern you see before you enter the decision phase. The pattern consists of 4 black and 5 white dots in a 3×3 matrix and will be displayed for **1 second** on the screen (see Figure A.5). Then the decision phase will start.

After the decision phase, you have to enter the pattern (see Figure A.6). You will see an empty matrix with 9 white dots. By clicking on the dots, you can change their color (from white to black or black to white). Click "OK" to confirm the pattern. If you **correctly** enter the pattern you may earn an additional **30** ECU.

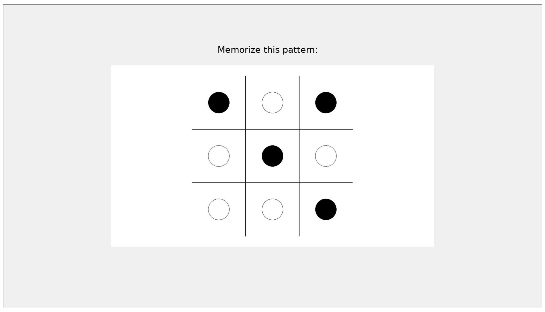


Fig. A.5 Memorizing a Pattern

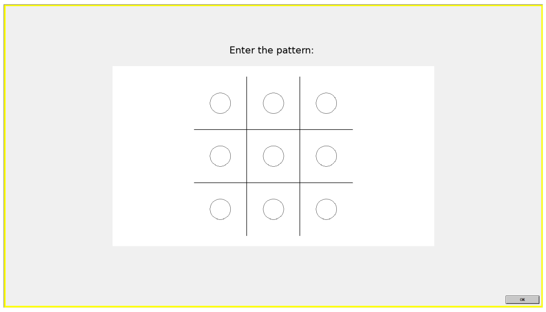


Fig. A.6 Input of the Memorized Pattern

You have to enter the pattern and click “OK” within 10 seconds, otherwise your answer will be automatically counted as wrong. For a wrong input, you will not receive any ECU.

At the end of the experiment one round with the additional task will be randomly selected. If you entered the correct pattern you will earn 30 ECU.

A.4 Repeating “And”

Instructions were verbal. Participants were required to complete the primary task while repeating the word “and” every 1.5 seconds, following the rhythm given by a metronome (this device was physically present on the table, i.e. not integrated into the computer program). They were instructed that successfully conducting this secondary task was a precondition for payment in the primary task.

A.5 Generating a Random Number Sequence

Instructions were verbal. Participants were required to name random numbers (from zero to nine) aloud at the rhythm of a metronome (this device was physically present on the table, i.e. not integrated into the computer program). They were instructed that successfully conducting this secondary task was a precondition for payment in the primary task.

B Experimental Tasks

B.1 Cournot Oligopoly Task (Experiments 1–3)

General Instructions

The experiment consists of **three parts with 17 rounds each** in which **you and three other participants** make decisions. After the completion of these three parts, a questionnaire will follow. In each of the three parts you will **earn points**. How many points you earn depends on your decisions and the decisions of the players in your group. All points you earned each round will be added up at the end of the experiment and exchanged into Euros. The exchange rate is:

1000 **points**= 20 **Eurocents.**

Independently of your decisions, you will receive 2.50 Euro for your participation. The total amount will be paid **in cash** and **anonymously** at the end of the experiment.

On the following pages you will receive all further information that you need for the experiment. Among other things, the sequence of the experiment will be explained in detail. Once you have finished reading the instructions, please proceed to answer the control questions on the screen.

Instructions for the Experiment

General Sequence: The experiment is divided into **three parts**. The **procedure is the same** for each part. Only the payoff table (which will be discussed later in more detail) and the composition of the groups change with each part. One part consists of **17 rounds**. At the beginning of each part, participants will be divided into groups. One **group** consists of **4 players** (you included) and stays the same for the duration of a part. That means that, during one given part, you always interact with the same players. For every new part, two of players will be replaced and therefore the composition of the group **changes**. That means that in a new part you do not interact with the same players as in the previous part.

In every round you have to decide among four options, A, B, C, or D. How many points you earn in one round depends both on your choice and on the choices of the other three group members. In addition, you can earn additional points in every round *Experiment 1]* / in 8 randomly-selected rounds in each part *[Experiments 2–3:]*.

Payoff Tables: The payoff tables are an important component of the experiment. They show you all possible payoffs depending on your choice and the choice of the other three group members. The rows represent your choice and the columns represent the joint choice of the other group members. The appropriate cell entry is the amount of points you would receive if this combination of choices occurs. Please note that for your payoff it is irrelevant which of the other group members made which choice. That means that if the other group members choose C, A, and B, respectively, this has the same effect on your payoff than if they choose A, B, and C. For a better overview, columns are ordered alphabetically.

Figures B.1-B.3 display examples of such payoff tables. Please note that in the experiment other payoff tables will be used.

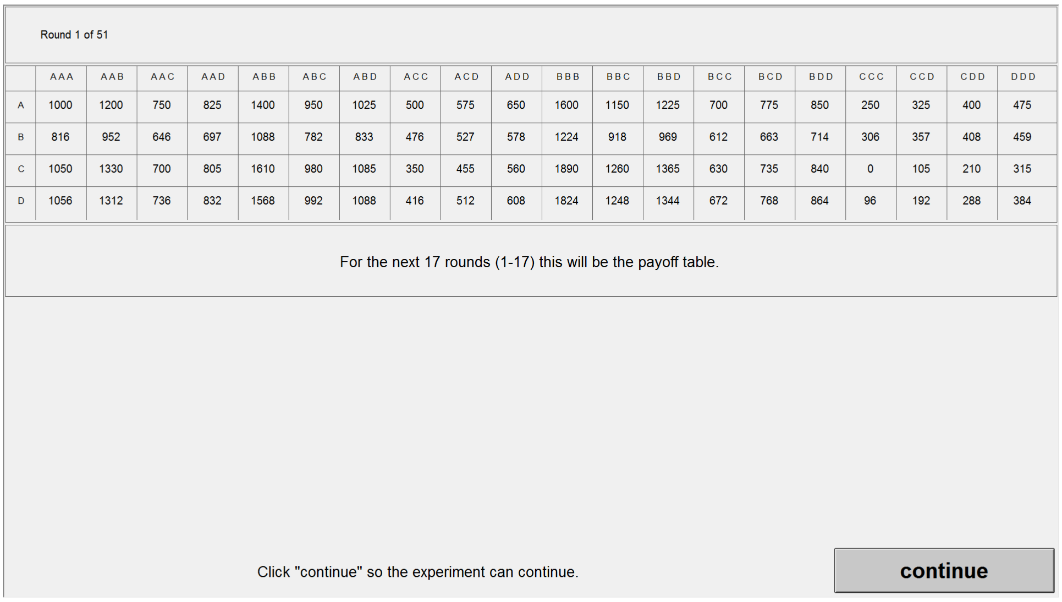
Important note: The payoff table will not change during a part. The same payoff table applies to all group members.

Your Decision: In each round you have to choose one of the four options, A, B, C, or D.

You have 30 seconds to make your choice. You make a choice by clicking on the appropriate button on the screen. During your choice the payoff table of the current part will be shown. The next round begins as soon as all participants made their choice. In every round the result of the previous round is shown (except for the first round of every part).

Sequence of Decisions in a Round in Detail: The **payoff table** will be shown at the beginning of each part so you can familiarize yourself with it (see Figure B.1[12]). The table will be kept on the screen during the experiment at all times – you **do not** need to memorize or copy the table. After you have familiarized yourself with the table click "continue." The **decision phase** will start as soon as all participants are ready. Now you can choose among **four options**, A, B, C, and D. To make a choice click the appropriate button of your choice (see Figure B.2).

[12] The payoff tables in the instructions were just illustrative. They were computed using $P(Q) = 140 - Q$, $A = 25$, $B = 17$, $C = 35$, $D = 33$.



Round 1 of 51

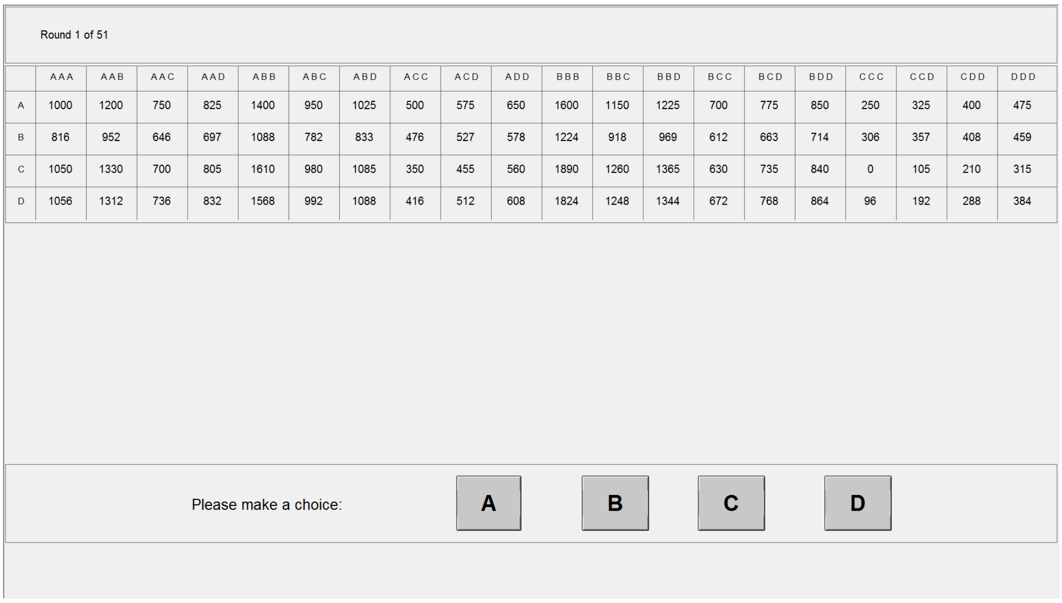
	AAA	AAB	AAC	AAD	ABB	ABC	ABD	ACC	ACD	ADD	BBB	BBC	BBD	BCC	BCD	BDD	CCC	CCD	CDD	DDD
A	1000	1200	750	825	1400	950	1025	500	575	650	1600	1150	1225	700	775	850	250	325	400	475
B	816	952	646	697	1088	782	833	476	527	578	1224	918	969	612	663	714	306	357	408	459
C	1050	1330	700	805	1610	980	1085	350	455	560	1890	1260	1365	630	735	840	0	105	210	315
D	1056	1312	736	832	1568	992	1088	416	512	608	1824	1248	1344	672	768	864	96	192	288	384

For the next 17 rounds (1-17) this will be the payoff table.

Click "continue" so the experiment can continue.

continue

Fig. B.1 Beginning of a Part



Round 1 of 51

	AAA	AAB	AAC	AAD	ABB	ABC	ABD	ACC	ACD	ADD	BBB	BBC	BBD	BCC	BCD	BDD	CCC	CCD	CDD	DDD
A	1000	1200	750	825	1400	950	1025	500	575	650	1600	1150	1225	700	775	850	250	325	400	475
B	816	952	646	697	1088	782	833	476	527	578	1224	918	969	612	663	714	306	357	408	459
C	1050	1330	700	805	1610	980	1085	350	455	560	1890	1260	1365	630	735	840	0	105	210	315
D	1056	1312	736	832	1568	992	1088	416	512	608	1824	1248	1344	672	768	864	96	192	288	384

Please make a choice: A B C D

Fig. B.2 Decision in the First Round of a Part

Starting in round two of each part, the **results from the previous round** will be shown (see Figure B.3). In the first column, "Results," you see the choices of all four players in the group. In the example figure it was "B, D, B, C." The first letter ("B") always represents your own choice whereas the following three letters ("D, B, C") represent the choice of the other three members of your group. The position of a letter (choice of a group member) is always assigned to a specific group member and stays the same during a given part. In the example the "left" player chose D, the "middle" player chose B, and the "right" player chose C.

In the second column, "Your Choice and Points," you will see your own choice and the points you earned in the previous round. In the example in Figure B.3 you can see in the payoff table that you earned 663 points because you chose B (row "B" in the

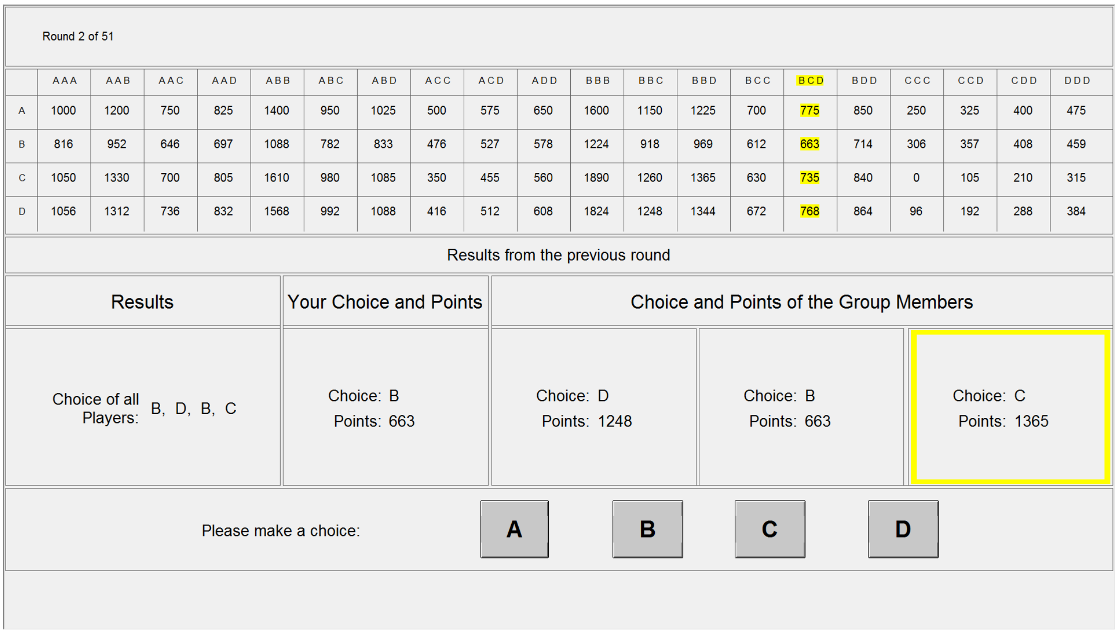


Fig. B.3 New Choice and Result of the Previous Round (Starting from the Second Round)

table) and the other group members chose D, B, C (column "B C D"). In the table, the column representing the choice combination of the group members is highlighted in yellow. The columns are ordered alphabetically for a better overview.
The last column, "Choice and Points of the Other Group Members," shows the choices and how many points the other group members earned in the previous round. The ordering of the group members is the same as in the first column, "Result" ("left" player – D, "middle" player – B, and "right" player – C).

The choice and points of the player who earned the most points in the previous round is highlighted in yellow. The column "Your Choice and Points" is also highlighted in yellow if you earned the most points in the previous round. In case of a tie the choice and points of multiple players will be highlighted.

Additional Points: *The instructions of the cognitive load task were included here. See Section Auditory Load and Remembering a Numerical Sequence for the instructions for the cognitive load tasks employed.*

B.2 Voting Task (Experiments 4–6)

General Instructions

The experiment consists of **three decision parts, and a questionnaire.**

In the decision parts, you will be able to earn experimental currency units (ECU). The amount of ECU you earn depends on your decisions and the decisions of other participants in the experiment. At the end of the experiment, the total amount of ECU you have earned during the experiment will be converted to EURO. The exchange rate for ECU to EURO is as follows.

1 ECU = 0.12 Euro, that is, 100 ECU = 12 Euro

Additionally, you will receive a show up fee of 4 Euro independently of your decisions during the experiment. The sum of your earnings will be paid to you in cash and privately at the end of the experiment.

Instructions for the Experiment

Voting decisions: In each of the four decision parts, you will participate in a series of elections. For this purpose, you are assigned to a group with 5 other, randomly chosen participants. **Each decision part will use a different voting method, which will be explained to you in detail at the beginning of the respective decision part.** There are up to four available alternatives, A, B, C, and D, that you can vote for.

Cast a Ballot: In each round, your task is to cast a valid ballot for the voting method used in that round. Please note that you are not allowed to abstain, that is, you have to submit a valid ballot for each of the elections.

Payment: At the end of the experiment **one election will be randomly selected** and the result of **that election** determines your payoff in ECU. It does not matter whether you voted for the winner or not. Your payoff **only** depends on the outcome of the election, that is, which alternative is declared the **winner** of the election. Your payoff profile, that is, the amount of ECU you earn depending on which alternative is the winner, will be shown to you on screen in each round. Your payoff profile and the payoff profiles of the other participants may change from round to round.

Additional Points: *The instructions of the cognitive load task were included here. See Section Remembering a Numerical Sequence and Remembering a Visual Pattern for the instructions for the cognitive load tasks employed.*

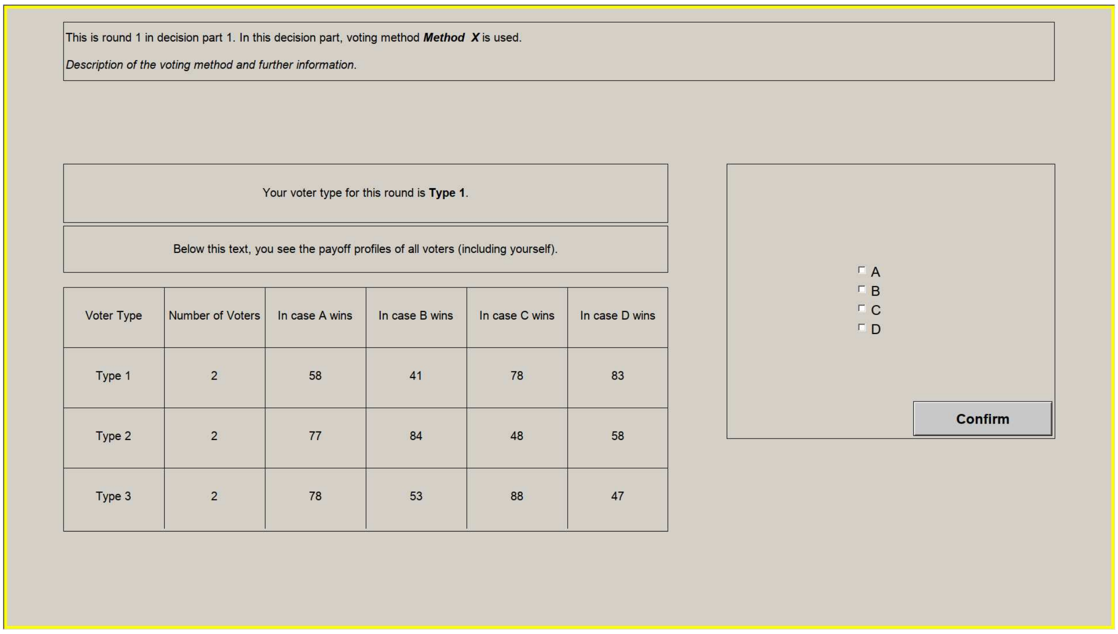
The Voting Interface

The example below shows a typical decision screen. However, the screens will look slightly different depending on which voting method is used. The exact numbers used in this example are only meant as an illustration; the general layout of the screen, however, will be the same in the experiment.

- At the top of the screen, you see the current voting round. Further, you will find there a description of the voting method used in this round.
- Directly below on the left, you will see your type for this round. In this example, you are a voter of type 1.
- The box at the bottom left of the screen shows the payoff profiles of all six voters in your group (yourself included) in the form of a table.
- On the right, you see the ballot with the available alternatives. Depending on the voting method, the exact form of the ballot may vary. Please fill in the ballot according to the description of the voting method used in that round. In this example, you can vote for an alternative by checking the corresponding box next to that alternative. You can submit your ballot by pressing the "Confirm" button.

How to read your payoff profile: In the example above, you would earn the following payoff in ECU depending on which alternative wins the election.

- If alternative A wins, then you receive 58 ECU.



Voter Type	Number of Voters	In case A wins	In case B wins	In case C wins	In case D wins
Type 1	2	58	41	78	83
Type 2	2	77	84	48	58
Type 3	2	78	53	88	47

Fig. B.4 Example Screenshot of Voting Decisions

- If alternative B wins, then you receive 41 ECU.
- If alternative C wins, then you receive 78 ECU.
- If alternative D wins, then you receive 83 ECU.

If in this example alternative B wins the election, then your payoff is 41 ECU. In this case, you will receive this amount independently of whether you have voted for alternative B or not. Only the winning alternative of the election determines your payoff. Please note that the payoff profiles in the experiment will differ from this example.

How to read the payoff profiles of the other voters: On the bottom left of the screen you see the payoff profiles of all voters in your group. This includes your payoff profile. The first column shows the the different types of voters. The second column shows the number of voters who have the payoff profile of the corresponding type. In this example, you are a voter of type 1, that is, your payoff profile is the one shown in the row labeled "Type 1." In this case you are one of two voters with this payoff profile, that is, there is one other voter with this profile, there are two other voters with the profile in the row labeled "Type 2," and two other voters with the payoff profile shown in the row labeled "Type 3."

In this example, the row labeled "Type 1" indicates that a voter of type 1 receives 58 ECU if alternative A wins the election, 41 ECU if alternative B wins the election, 78 ECU if alternative C wins the election, and 83 ECU if alternative D wins the election. The second row indicates that voters of type 2 receive 77 ECU if alternative A wins the election, 84 ECU if alternative B wins the election, 48 ECU if alternative C wins the election, and 58 ECU if alternative D wins the election. The last row indicates, that voters of type 3 receive 78 ECU if alternative A wins the election, 53 ECU if alternative B wins the election, 88 ECU if alternative C wins the election, and 47 ECU if alternative D wins the election.

Note that the total number of voters represented in the table adds up to 6. That is, the table contains the payoff profiles of all voters in your group: **Your payoff profile**

and the payoff profiles of the 5 other voters. Please remember that the payoff profiles in the experiment will differ from this example.

Comprehension Questions

Please answer the following comprehension questions by clearly marking the correct answer.

- Question 1: The payoff in ECU that you can earn in a given voting round depends on

  which alternative wins the election　　　　which alternative I vote for

- Question 2: I receive a payoff for the election outcome of

  every election　　　　one randomly selected election

- Question 3: In each round, I know the payoff profiles of the other five voters in my group, true or false?

  true　　　　false

- Question 4: Consider the payoff profile from the example above. How many of the other voters in your group have the same payoff profile as you?

  2 other voters　　　　1 other voter

- Question 5: Consider the payoff profile from the example above. If you are a voter of type 1 in this example, what is your payoff if alternative C wins the election?

  78 ECU　　　　48 ECU　　　　88 ECU

- Question 6: I earn additional points for correct answers to the additional task for:

  each round　　　　one randomly selected round

On-Screen Description of Voting Methods

Plurality Voting: For voting method 1, you can vote for exactly one alternative, and the alternative with the most votes is declared the winner of the election. In case of a tie between multiple alternatives, one of those alternatives is randomly selected as the winner, with all tied alternatives having the same probability of being selected.

Approval Voting: For voting method 2, you can approve of as many alternatives as you wish. All alternatives you approve of will receive one vote, that is, all your approvals are weighted equally. The alternative with the most approvals is declared the winner of the election. In case of a tie between multiple alternatives, one of those alternatives is randomly selected as the winner with all tied alternatives having the same probability of being selected.

Random Dictator: For voting method 3, you and the other 5 voters make a decision, however, only the decision of a single voter will determine the outcome of the election. One of the 6 voters (yourself included) will be randomly selected and this voter's decision will determine the outcome independently of the decisions of the other voters.

For this voting method, you first select one alternative. However, there is a small probability of 5% that the alternative you have selected cannot be implemented. Therefore, in a second step you have to select a second alternative, in case your first selection cannot be implemented. Select as your second alternative the alternative that you would select if the first one were not available. Also for this second alternative there is a small probability of 5% that it cannot be implemented. Thus, in a third step you have to select a third alternative. Select as your third alternative, the alternative that you would select if the two alternatives you have selected so far were not available.

B.3 Bayesian Updating (Experiment 7)

General Instructions

There are two containers ("urns") displayed on the screen. These urns contain white and black balls. The objective of this game is to draw as many black balls as possible. For this you have to draw cleverly from both urns according to certain rules. The following part describes the elements on the screen and how to use the keyboard. The rules of the game are explained later.

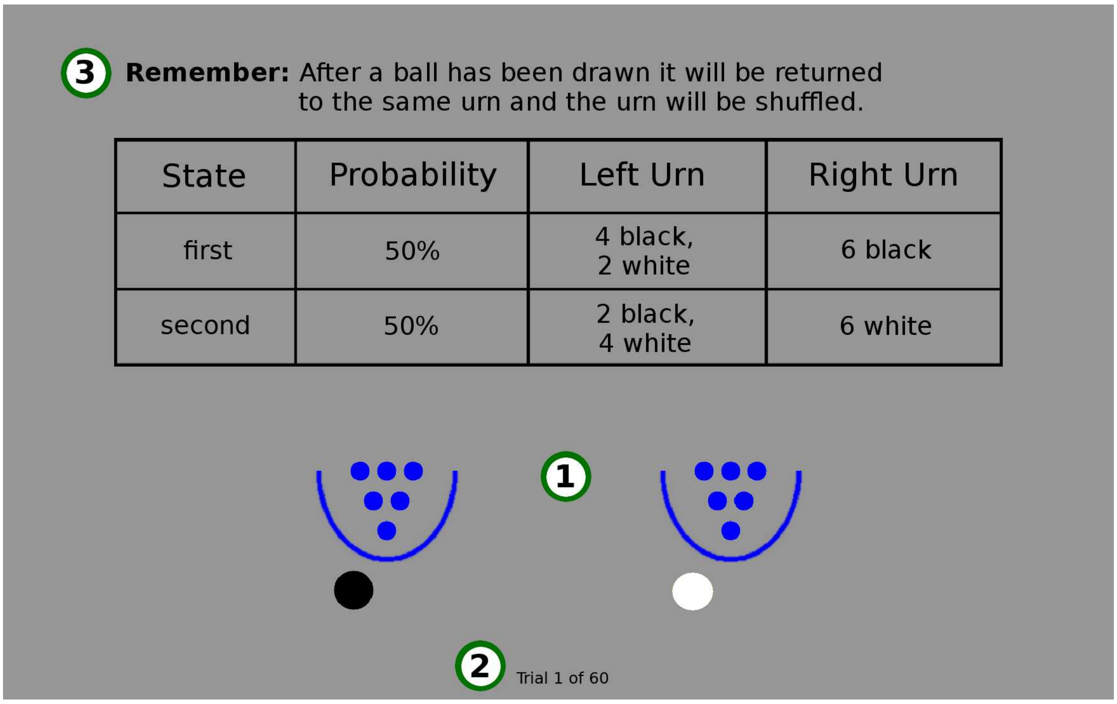


Fig. B.5 Instructions Screenshot

Interface

1) The bottom half of the screen displays two urns. Each urn contains six balls. There are black and white balls which will be colored blue as long as they are "hidden" inside the urn. Below the urns are the balls that have already been drawn during this trial (e.g. a black and a white ball).

   Note that: *When an urn is colored gray you cannot draw a ball out of this urn and you have to choose the other urn. After you make a choice the urns turn gray temporarily and you cannot select any urn.*

2) The number of the current trial is displayed at the center of the top of the screen display.

3) The upper part of the screen summarizes the most important information and the rules of the game.

To make decisions you only need three keys. Two of these keys are marked on the keyboard using small yellow dots. With the left key ("F") you draw a ball out of the left urn and with the right key ("J") out of the right urn. You start a new trial by pressing the space bar when you are prompted to do so on screen.

Rules

Procedure: There are a total of 60 trials, each of which consists of two draws. In each trial, you select an urn to draw a ball from it by pressing the appropriate key. During the first 30 trials, you have to draw the first ball out of a predetermined urn, the left one in odd trials (1, 3, 5, etc.) and the right one in even trials (2, 4, 6, etc.). During the last 30 trials, you can freely choose out of which urn the first ball shall be drawn. You will recognize this by the color of the urns. You can only draw from an urn when the urn and balls in it are colored blue. After choosing the urn a random ball will be drawn from the urn. The result of the first draw (black or white) will be displayed below the urn and you will then draw again. After a ball is drawn both urns will turn gray for a moment, which means that you cannot draw another ball at that time. When the urns turn blue you can draw again from the urns. The result of the second draw will be displayed below the appropriate urn. Finally, you will be prompted to press the space bar to start a new trial.

Note that: *A drawn ball will be replaced immediately into the same urn! Drawing a ball out of the urn will not change the composition of black and white balls in the urn between the first and second draw. You draw both times from the exact same urns.*

Payoff: For every black ball you draw you will earn 18 cents; you will not earn anything for drawing a white ball. With a bit of luck and clever drawing out of the urns you can earn a considerable amount of money!

States of the World: The most important part of the game is to understand how many black and white balls are in the urns. Please read the following part very carefully! In this experiment there are two states of the world:

In the **first state of the world** there are 4 black and 2 white balls in the left urn and 6 black balls in the right urn.

In the **second state of the world** there are 2 black and 4 white balls in the left urn and 6 white balls in the right urn.

As mentioned above, you draw one ball out of an urn, which will be put back into the urn, and then you draw a second time. However, you do not know whether the state of the world for this specific trial is the first or second one. The state of the world will be determined randomly by the computer. The chance for the first or second state of the world is 50%. The state of the world does not change during a trial!

Summary: The table below summarizes the two states of the world:

State of the world	Chance in each trial	Left Urn	Right Urn
first	50%	4 black, 2 white	6 black
second	50%	2 black, 4 white	6 white

To be able to draw many black balls it is important that you understand the table above. If you have any questions, please ask the experimenter.

Additional Task: *The instructions of the cognitive load task were verbally explained by the experimenter. See Section Repeating "And" and Generating a Random Number Sequence for the instructions for the cognitive load tasks employed.*