The self-regulation of information processing and decision making

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Abstract

The present thesis investigates whether people can strategically regulate their information processing (Research Papers I and II), and the effects of strategic information processing on decision making (Research Paper III). These topics are addressed from the perspective of the self-regulation strategy of if-then planning (also referred to as implementation intentions).

The first research paper tested the hypothesis that if-then planning enhances perceptual processing. Two experiments were based on a psychological refractory period (PRP) paradigm and showed an underadditive interaction effect of if-then planning and stimulus onset asynchrony (SOA), suggesting that making if-then plans indeed enhances perceptual processing. The third experiment used an additive factors logic and supported this conclusion by showing an interaction effect of if-then planning and stimulus brightness. Taken together, Research Paper I suggests that if-then planning enables people to strategically regulate perceptual information processing.

While the first research paper focused on perceptual processing, the second research paper scrutinized if-then planning effects in a more comprehensive manner. Across three Eriksen flanker task experiments, participants were faster in classifying a central target stimulus when they planned their response to this stimulus in an if-then plan, without a drop in accuracy. Fitting these data with the dual-stage two-phase (DSTP) sequential sampling model revealed increased drift rates for stimuli specified in an if-then plan compared to non-planned stimuli during early stimulus and response selection (Experiment 1), and additional increases during late stimulus and response selection when the task entailed response conflict (Experiment 3). This pattern of findings expands those obtained in the first research paper, indicating that people can strategically regulate even how efficiently they process information when selective attention is required.

Finally, the third research paper investigated how self-regulated information processing affects decision making in an ultimatum game paradigm. Participants planned to adopt an intuitive or a reflective mode of processing, or made no such plans in a control condition, before deciding to accept or
reject a series of 10 ultimatum offers including very low (unfair) ones. Participants adopting a reflective mode of processing were more likely to accept unfair offers than those adopting an intuitive mode. This effect was further moderated by participants’ social value orientation (SVO), a simple measure of prosociality that we had assessed prior to the experiment: Prosocials were much less likely to accept unfair offers than selfish people when they adopted an intuitive mode of processing, whereas no such difference evinced in the reflective condition.

Taken together, the findings of these three research papers converge to the conclusion that people can strategically regulate how they process information in a way that affects their subsequent decisions. Besides its implications for research on the self-regulation strategy of if-then planning, the present thesis provides novel perspectives on human information processing and decision making, conceiving of them as a matter of strategic regulation.
Zusammenfassung

Die vorliegende Dissertation untersucht die menschliche Fähigkeit zu strategischer Informationsverarbeitung (Forschungsarbeiten I und II) sowie die Auswirkungen dieser strategischen Verarbeitung auf das Treffen von Entscheidungen (Forschungsarbeit III). Diese Themen werden aus der Perspektive der selbstregulatorischen Strategie des Wenn-Dann Planens (auch als Durchführungsintentionen bezeichnet) betrachtet.

Die erste Arbeit prüft die Hypothese, dass Wenn-Dann Pläne die perzeptuelle Verarbeitung verbessern. Zwei Experimente basieren auf einem Paradigma der psychologischen Refraktärperiode (engl. PRP) und zeigen einen unteradditiven Interaktionseffekt von Wenn-Dann Plänen und der Asynchronität des Stimulusbeginns (engl. SOA), was eine Verbesserung der perzeptuellen Verarbeitung durch das Formulieren von Wenn-Dann Plänen nahe legt. Das dritte Experiment bedient sich der Logik additiver Faktoren und stützt diese Schlussfolgerung, indem es einen Interaktionseffekt von Wenn-Dann Plänen und Stimulusleistung demonstriert. Insgesamt betrachtet stützt die erste Forschungsarbeit die Annahme, dass Menschen ihre perzeptuelle Informationsverarbeitung strategisch regulieren können.

Während die erste Forschungsarbeit sich auf perzeptuelle Informationsverarbeitung konzentriert hat, unterzieht die zweite Arbeit Wenn-Dann Planungseffekte einer umfassenderen Untersuchung. Über drei Eriksen FlankierungsAufgaben hinweg waren Teilnehmer in der Lage, einen zentralen Stimulus schneller zu kategorisieren, wenn sie ihre Reaktion auf diesen Stimulus vorab in einem Wenn-Dann Plan spezifizierten, ohne Abstriche hinsichtlich der Akkurate. Eine Anpassung des zwei-Stufen zwei-Prozess (engl. DSTP) sequentiellen Sampling-Modells an die Daten zeigt eine verbesserte Driftrate für Stimuli, die in einem Wenn-Dann Plan spezifiziert worden sind, verglichen mit nicht geplanten Stimuli, während der frühen Stimulus- und Reaktionswahl (Experiment 1). Zusätzliche Verbesserungen der Driftrate während der späten Stimulus- und Reaktionswahl zeigten sich bei einer Aufgabe mit Reaktionskonflikten (Experiment 3). Dieses Ergebnismuster erweitert die Befunde der ersten Forschungsarbeit durch die Demon-
stration, dass Menschen die Effizienz ihrer Informationsverarbeitung hinsichtlich der selektiven Aufmerksamkeit strategisch regulieren können.


In ihrer Gesamtheit legen die drei Forschungsarbeiten den Schluss nahe, dass Menschen ihre Informationsverarbeitung in der Tat strategisch regulieren können, und dass dies mit Konsequenzen für Ihre anschließenden Entscheidungen verbunden ist. Neben den Implikationen für die Forschung zu Wenn-Dann Plänen bietet die vorliegende Dissertation somit auch eine neue Perspektive auf menschliche Informationsverarbeitung und Entscheidungsfindung, indem sie diese als Gegenstand strategischer Regulation beschreibt.
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Synopsis

Can people strategically regulate their information processing? And if so, how does such strategic information processing in turn affect their decisions? The present thesis adopts a self-regulation perspective on information processing and decision making to address these questions.

Across three research papers, I have capitalized on the self-regulatory strategy of if-then planning, also referred to as forming implementation intentions (Gollwitzer, 1993, 1999, 2014), which has been studied primarily in the context of social and motivational phenomena. Its beneficial effects on goal attainment and action control in these domains are ubiquitous and well-documented, rendering if-then planning a promising tool to study the general human ability to regulate information processing and the consequences of such self-regulated information processing for decision making. Given the fundamental nature of this topic, I decided to strike an interdisciplinary path, availing myself of approaches from cognitive and social psychology, as well as behavioral economics. This allowed me to draw upon a wide range of research methods, including different task paradigms (perceptual and preference-based tasks) and analytical approaches (decision and process analyses).

The aim of this synopsis is to discuss the three papers in a common framework, showing how each of them contributes to the overarching topic of the present thesis. I will therefore proceed as follows: In the first section, I will introduce the self-regulation strategy of if-then planning, detail its effects on goal attainment and action control, and outline what is known about the processes underlying these effects. In the second section, I will focus on the question whether people can use if-then plans to strategically regulate their information processing; the primary topic of the first two research papers. In the third section, I will turn to the third research paper, which addresses the question how self-regulating information processing with if-then plans affects decision making. The final section provides a general discussion which points out implications of the present research and sketches promising directions of future research.
The Self-regulation Strategy of If-then Planning

Merely specifying a desired behavior or outcome (i.e., a goal intention, “I want X!”) has only small-to-medium effects on actual behavior ($d = 0.36$; Webb & Sheeran, 2006), giving rise to what is often called the intention-behavior gap (Sheeran, 2002): People struggle with achieving their goals because they fail to initiate an action in due time, to persevere in the face of obstacles, to preserve their resources, and/or to cease futile goal striving.

Furnishing goal intentions with if-then plans has been shown to help people dealing with these various problems of goal striving (Gollwitzer & Oettingen, 2011). Making an if-then plan means to mentally link a critical goal-relevant situation to a response that is instrumental to attain the goal (i.e., “If I encounter situation S, then I will initiate response R!”). This simple response strategy has powerful effects, facilitating the rate of goal attainment across a wide set of domains (e.g., health, achievement, and interpersonal; for recent reviews see Adriaanse, Vinkers, De Ridder, Hox, & De Wit, 2011; Bélanger-Gravel, Godin, & Amireault, 2013; Gollwitzer, 2014; Hagger & Luszczynska, 2014). A meta-analysis involving more than 8000 participants in 94 independent studies revealed that furnishing goal intentions with if-then plans has a medium-to-large effect on the rate of goal attainment ($d = 0.65$; Gollwitzer & Sheeran, 2006). How does if-then planning facilitate goal attainment, and how far do the effects of if-then plans reach? The following section reviews research on these questions.

Processes and effects

By planning out in advance how to respond in a specified situation, people with an if-then plan can strategically automate their behavior (Gilbert, Gollwitzer, Cohen, Oettingen, & Burgess, 2009). Gollwitzer (1993, 1999, 2014) has argued that this strategic automaticity is governed in concert by two distinct cognitive processes, often referred to as heightened stimulus accessibility and automatic response initiation.

First, the cognitive representation of the situation specified in the if-part becomes highly accessible and is thus easier to detect (Aarts, Dijksterhuis, & Midden, 1999; Webb & Sheeran, 2007), in particular because it receives an attentional advantage over other stimuli (Achtziger, Bayer, & Gollwitzer, 2012; Wieber & Sassenberg, 2006). Second, the mental link forged between situation and response allows to respond immediately (Gollwitzer & Brandstätter, 1997; Orbell & Sheeran, 2000), efficiently (Brandstätter, Lengfelder, & Gollwitzer, 2001; Lengfelder & Gollwitzer, 2001), and without a further conscious
intent (Bayer, Achtziger, Gollwitzer, & Moskowitz, 2009) as soon as the specified situation is encountered—central characteristics of automaticity (Bargh, 1994). As suggested by Gollwitzer (1993, 1999, 2014), heightened stimulus accessibility and the automaticity of response initiation together mediate the positive effects of if-then planning on goal attainment (Gollwitzer & Oettingen, 2011; Webb & Sheeran, 2007).

By enabling people to automate their goal-directed behavior, if-then planning serves as a self-regulation strategy for controlling even phenomena that are commonly assumed to reach beyond the realm of intentional control. For instance, the automaticity afforded by making if-then plans has been shown to curb automatic cognitive processes like priming effects (Gollwitzer, Sheeran, Trötschel, & Webb, 2011; Webb, Sheeran, Gollwitzer, & Trötschel, 2012), implicit attitudes (Webb, Sheeran, & Pepper, 2012), inhibition in Stroop and stop-signal tasks (Gawrilow & Gollwitzer, 2008; Webb & Sheeran, 2003), task switching (Cohen, Bayer, Jaudas, & Gollwitzer, 2008), stereotype activation and application (Gollwitzer & Schaal, 1998; Mendoza, Gollwitzer, & Amadio, 2010; Stewart & Payne, 2008), as well as habitual (Adriaanse, Gollwitzer, De Ridder, de Wit, & Kroese, 2011) or social (Wieber, Gollwitzer, & Sheeran, 2014) influences on behavior. Metaphorically speaking, if-then planning enables people to win the race against a variety of automatic processes that would outpace more deliberate forms of action control.

**Strategic Regulation of Information Processing**

As indicated by the research reviewed in the previous section, making if-then plans facilitates goal attainment by enabling people to strategically automate their goal-directed behaviors. Moreover, beneficial effects of if-then planning on goal attainment have been documented even for automatic cognitive processes that are commonly not subject to voluntary control. Together, these findings might be taken to suggest that if-then planning enables people to strategically regulate how they process information (e.g., more efficient processing of goal-relevant information). So far however there is no direct empirical investigation of this assertion, although this would substantially contribute to our understanding of if-then planning effects, and shed light on the general human capability to strategically self-regulate information processing. As I have argued elsewhere with my colleagues (Gollwitzer, Bieleke, & Sheeran, in preparation), evidence for such a capability would be of great practical relevance as well.
Studying whether if-then planning indeed enables people to strategically regulate how they process information requires approaches that allow to draw firm conclusions about information processing. I therefore turned to cognitive psychology—a field that virtually defines itself as the study of how humans process information (e.g., Neisser, 1967). One prominent approach to investigate information processing in cognitive psychology is by means of \textit{mental chronometry} (e.g., Linden, 2007; Meyer, Osman, Irwin, & Yantis, 1988; Pachella, 1974; Posner, 1978). The main assumption of mental chronometry studies is that features of information processing can be inferred from overt response characteristics, in particular the speed and accuracy of responses. This is commonly applied in rather simple tasks by requiring participants to respond to sensory (e.g., perceptual or auditory) stimuli. Broadly speaking, two general approaches can be distinguished within mental chronometry (Meyer et al., 1988), mainly differing in whether they primarily focus on response times (the approach taken in Research Paper I) or investigate response times and response accuracy jointly (the approach taken in Research Paper II) to study human information processing.

\textbf{Research Paper I: The Benefit of no Choice}

The first approach in mental chronometry emphasizes that information processing can be divided into separate stages which are characterized by distinct cognitive operations (e.g., Donders, 1868/1969; McClelland, 1979; J. Miller, 1982; Sternberg, 1969)—such as perceptual processing, response selection, and motor processes—and focuses on response times to study these stages. The general idea is that response times reflect the overall duration of passing all stages, that is, of completing the corresponding cognitive operations. Under this assumption, information processing can be investigated by analyzing the additive and interactive effects of various manipulations on response times, as this will reveal the stage(s) at which these manipulation affect information processing.

In the present research, the manipulation of interest is if-then planning. Based on past research demonstrating that if-then planning allows people to more readily detect and attend to the stimulus specified in the if-part (e.g., Aarts et al., 1999; Achtziger et al., 2012; Webb & Sheeran, 2007; Wieber & Sassenberg, 2006), in the first research paper we hypothesized that if-then planning enhances perceptual information processing, as indicated by a shorter perceptual stage. We tested this hypothesis in three experiments.
Experiments 1a, 1b, and 2: PRP paradigm

The psychological refractory period (PRP) paradigm. The first two experiments draw upon a psychological refractory period (PRP) paradigm (Pashler, 1994; Telford, 1931), in which people respond to two successive stimuli S1 and S2 with responses R1 and R2, respectively. It is commonly observed that reducing the interval between presenting the two stimuli (i.e., shortening the stimulus onset asynchrony [SOA]) slows down the response to S2, whereas responses to S1 are barely affected by variations in SOA.

A widely accepted account for this PRP effect is the central bottleneck model (Pashler, 1994; Welford, 1952), which subdivides information processing into three consecutive stages: (1) a pre-central, perceptual stage, (2) a central stage of response selection, and (3) a post-central, motor stage. Crucially, response selection is assumed to constitute a central bottleneck because only one central stage can be processed at any time. In contrast, pre- and post-central stages can be processed in parallel with all other stages.

How can the central bottleneck model explain the PRP effect? With short SOAs, perceptually processing S2 is already completed while S1 still occupies the central processing stage. Accordingly, central processing of S2 will be postponed until S1 releases the central stage, resulting in a cognitive slack that is reflected in a slower response to S2. With longer SOAs, the cognitive slack becomes shorter and eventually disappears, zeroing out the PRP effect.

The locus of slack logic. Importantly, this reasoning can be used to test hypotheses about the perceptual effects of experimental manipulations, such as making if-then plans. Assume that the manipulation of interest affects the perception of S2 (i.e., it changes the duration of the pre-central, perceptual stage of processing). With short SOAs, the manipulation effects are masked by the cognitive slack because centrally processing S2 cannot commence until S1 releases the central stage, thwarting the translation of perceptual differences between manipulations into the overall response time. With longer SOAs, in contrast, the slack disappears and differences in perceptual processing are reflected by faster responses to S2. This locus-of-slack logic (Schweickert, 1978) implies an underadditive interaction effect of the manipulation and SOA: the manipulation effect is weaker at short compared to long SOAs. Such an underadditive interaction effect has indeed been reported for several manipulations affecting perceptual performance (e.g., stimulus intensity).
The effects of if-then planning on perceptual processing. According to the locus-of-sack logic, our hypothesis that if-then planning enhances perceptual processing requires an underadditive interaction effect of if-then planning and SOA. We tested this prediction in the first two experiments by comparing response times to S2s that were linked to a specific response in an if-then statement (forced-choice task) with S2s that were not linked to a specific response (i.e., a free-choice task). Across both experiments, we observed the predicted underadditive interaction effect of if-then planning and SOA. Specifically, participants responded faster to S2s in the forced-choice (if-then planning) compared to the free-choice task at long SOAs, whereas no such difference evinced at short SOAs.

Experiment 3: Additive-factors paradigm

The additive-factors paradigm. Experiment 3 corroborated the results of the PRP experiments using an additive-factors paradigm (Sternberg, 1969). Whereas PRP studies vary the SOA between two successive tasks to localize the effects of a manipulation on information processing, additive-factors paradigms combine two manipulations in a single task and focus on their additive versus interactive effects on response times. While an additive effect is taken to indicate that the two manipulations affect different stages of information processing, an interactive effect suggests that both manipulations operate at the same stage.

The effects of if-then planning on perceptual processing. Following this logic, we manipulated stimulus brightness—which has well-documented effects on perceptual processing—and also varied whether responses to stimuli were specified in if-then plans (forced-choice) or not (free choice) prior to a color identification task. Assuming that if-then planning enhances perceptual processing, we expected an interaction effect of stimulus brightness and if-then planning. Our data confirmed this prediction. Responses were faster in the forced- compared to the free-choice tasks when the stimuli were bright, but no such difference evinced for dark stimuli, giving rise to a significant interaction effect of stimulus brightness and task type.

Conclusion

Across three experiments, Research Paper I demonstrates that if-then planning enhances perceptual information processing. Participants responded faster to stimuli when they planned how to respond to these stimuli (forced-choice task) rather than making no such plans (free-choice task). This finding
complements and advances prior research on the attentional consequences of making if-then plans (Achtziger et al., 2012; Wieber & Sassenberg, 2006) and supports the hypothesis that people are generally able to regulate their information processing in a strategic manner.

However, this first research paper focused exclusively on early perceptual processing, as none of the experiments explicitly checked under which circumstances if-then planning might have additional effects on information processing, such as response selection (i.e., the central processing stage). This might, however, well be the case, in particular when the task becomes more complex and, for instance, response selection requires attentional selectivity in addition to perceptual processing. To overcome this limitation, Research Paper II studied a perceptual task that allowed to manipulate the degree of response conflict, thus varying the importance of attentional selectivity for response selection, and it turned to the second branch of mental chronometry previously mentioned.

**Research Paper II: If-then Planning Enhances Selective Attention**

Studies using the second approach in mental chronometry mentioned above focus not only on response times, but additionally incorporate response accuracy into the analysis, often investigating how people trade-off between responding quickly versus accurately (e.g., Fitts, 1966; Wickelgren, 1977; Woodworth, 1899). As a consequence, this approach permits a detailed and comprehensive analysis of peoples’ ability to strategically regulate their information processing. One example are computational sequential sampling models (e.g., Brown & Heathcote, 2008; Hubner, Steinhauser, & Lehle, 2010; Ratcliff, 1978; Ratcliff & McKoon, 2008; P. L. Smith & Van Zandt, 2000; Usher & McClelland, 2001) which simultaneously account for entire response time and error distributions, thus capitalizing most of the available information.

These models conceive of information processing as the accumulation of noisy evidence about a sensory stimulus, and this evidence accumulation can be characterized in various ways. In particular, fitting a sequential sampling model to experimental data results in a set of parameter estimates which represent these characteristics. Examples include the speed of evidence accumulation (often referred to as drift rate, parameter \( \mu \)), the duration of non-decisional components such as stimulus encoding and motor activity (parameter \( t_{er} \)), and the amount of evidence sampled before a decision is made (parameter \( a \)).
The Eriksen flanker task. In the second research paper we used Eriksen flanker tasks (B. A. Eriksen & Eriksen, 1974) which require responses to a central target item, while flanking non-target items have to be ignored. It is commonly observed that people struggle with fully ignoring the distracting flankers, as they respond more slowly and/or make more errors when the flankers activate a different (incongruent) rather than the same (congruent) response as the target—referred to as the flanker congruency effect.

In our study, we used flankers that were either response-neutral (i.e., were not associated with a response; Experiment 1) or varied between response-congruent and response-incongruent across trials (Experiments 2 and 3). Thus, in Experiment 1 response selection primarily required perceptual processing (similar to Research Paper I), whereas Experiments 2 and 3 entailed response conflict and thus increased the importance of attentional selectivity for response selection.

The sequential sampling approach We relied on the dual-stage two-phase (DSTP Hübner et al., 2010) sequential sampling model because it can account for data from tasks involving response conflict, such as the Eriksen flanker task used in this research paper. In contrast to other sequential sampling models, the DSTP model estimates several different drift rates rather than a single one: the rate $\mu_{RS1}$ depends on the quality of early stimulus selection (i.e., weighing and filtering) and reflects the initial efficiency of selecting a response, $\mu_{SS}$ corresponds to the efficiency of late stimulus selection (i.e., categorization), and $\mu_{RS2}$ reflects how efficiently a response can be selected once stimulus selection has been completed.

This structure of the DSTP model allowed to fully scrutinize the effects of if-then planning on information processing, and thus to obtain a comprehensive account of how people can regulate their information processing. As the task used in Experiment 1 did not entail response conflict and primarily required perceptual performance, we expected if-then planning effects on the efficiency of early stimulus and response selection, reflected by the drift rate $\mu_{RS1}$ (i.e., the quality of filtering and weighting perceptual information). The task used in Experiments 2 and 3, on the other hand, entailed response conflict, and therefore put increased demands on attentional selectivity. Accordingly, we expected not only enhanced early stimulus and response selection as in Experiment 1 (captured by an increased drift rate $\mu_{RS1}$), but also a more efficient late stimulus and response selection, as indicated by additional increases of the drift rates $\mu_{SS}$ and $\mu_{RS2}$, respectively.

We also considered the possibility that the effects of making if-then plans show up in the non-decisional component $t_\text{er}$, potentially reflecting a speed-
up in motor responses. However, we did not expect variations in the amount of evidence sampled before making a decision as a possible source of implementation effects. This would manifest as a speed-accuracy tradeoff (e.g., making faster decisions at the cost of committing more errors) which is inconsistent with prior research on if-then planning (e.g., Brandstätter et al., 2001).

**The effects of if-then planning on information processing.** On a behavioral level, our straightforward prediction was that participants should respond faster and/or more accurate to the stimulus specified in their if-then plan than to other stimuli, as numerous studies have shown that if-then planning automates the initiation of goal-directed behavior (Gollwitzer & Sheeran, 2006). In line with this hypothesis, we observed faster responses to stimuli specified in an if-then plan than to other stimuli, without a drop in accuracy. Experiment 1 additionally tested whether these effects could be ascribed to increased stimulus familiarity or enhanced motivation to perform well, rather than reflecting a unique effect of if-then planning. However, we found no evidence for this reasoning, as performance did not vary as a function of familiarity and motivation alone.

Importantly, fitting the DSTP model to the data further confirmed our hypotheses regarding the effects of if-then planning on information processing. In Experiment 1, we observed the predicted higher drift rate \( \mu_{RS1} \) for stimuli specified in an if-then plan compared to other stimuli. Furthermore, the parameter estimates in Experiment 3 revealed significantly higher drift rates \( \mu_{RS1}, \mu_{SS}, \mu_{RS2} \) for stimuli specified in an if-then plan compared to other stimuli. No other effects on information processing (e.g., variations in the non-decisional component \( t_{er} \)) were reliable in our experiments.

**Conclusion**

The results of Research Paper II corroborate those obtained in the first research paper by indicating that if-then planning facilitates perceptual processing (i.e., sensory weighting and filtering). This is an interesting finding, as both the task requirements (respond to successively presented relevant information versus discern between simultaneously presented relevant and irrelevant information) and the method to investigate information processing (PRP and additive-factors paradigms versus sequential sampling modeling) varied between the two papers.

Moreover, the second research paper demonstrates enhanced stimulus and response selection in a task entailing response conflicts, that is, when the demands on attentional selectivity for selecting the correct response are high.
This corroborates the conclusion that people can strategically self-regulate their information processing by making if-then plans, and extends this conclusion to stimulus and response selection in a comprehensive manner.

**Strategically Regulated Information Processing and Decision Making**

Research Papers I and II indicate that people are able to strategically regulate how they process information. However, both papers reveal little insight into the consequences of engaging in such strategic regulation. Does strategically regulating information processing have meaningful consequences for decision making; and if so, what are the characteristics of these consequences? One way to address these questions is to encourage people to regulate their mode of information processing with if-then plans while they make decisions. This is a novel approach in research on if-then planning, which has so far limited itself to studying the initiation of specific goal-directed responses rather than modes of information processing.

To investigate the consequences of self-regulated information processing, I turned to the field of behavioral economics, which is concerned with examining how people make decisions in a variety of domains (e.g., under risk and uncertainty, when facing intertemporal trade-offs, or when interacting with other people; Camerer, 2003; Camerer, Loewenstein, & Rabin, 2004). Information processing in behavioral economics can be described in terms of dual-process models (e.g., Alós-Ferrer & Strack, 2014; Chaiken & Trope, 1999; Evans, 2008; Haidt, 2001; Kahneman, 2011; E. R. Smith & DeCoster, 2000; Strack & Deutsch, 2004; Weber & Johnson, 2009). According to these models, decision making is governed by two modes of information processing that can be adequately captured by the terms “intuitive” and “reflective.” Intuitive information processing is assumed to be fast and efficient, not relying on resources such as time and cognitive capacity, whereas reflective information processing is characterized as being slow and resource-demanding.

The effects of engaging in intuitive versus reflective modes of processing on decision making are commonly investigated by facilitating intuitive processing (e.g., cognitive load; Schulz, Fischbacher, Thöni, & Utikal, 2014) versus reflective processing (e.g., time delay; Neo, Yu, Weber, & Gonzalez, 2013), and examining the effects of these manipulations on overt decisions. Research Paper III adopts such a dual-process perspective to study the effects of self-regulated information processing on decision making. Specifically, it
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examines how planning to adopt an intuitive versus a reflective mode of processing affects responses to unfair ultimatum offers.

Research Paper III: Information Processing in the Ultimatum Game

In the third research paper, we varied whether people engaged in intuitive versus reflective information processing by means of if-then planning. As demonstrated in the first two research papers, people can strategically regulate how they process information, and should thus also be able to strategically adopt an intuitive versus a reflective mode of processing. Moreover, prior research has demonstrated that planning specific reflective responses has effects on decisions, such as making investments that are well aligned with available feedback (e.g., Wieber, Thürmer, & Gollwitzer, 2015). Taken together, these findings might be taken to assume that people can strategically engage in intuitive versus reflective information processing, and that this strategic processing has meaningful consequences for their decisions.

Responses to unfair offers in the ultimatum game

In our experiment we used an ultimatum game paradigm (Güth, Schmittberger, & Schwarze, 1982; see Güth & Kocher, 2014, for review), in which a proposer receives a certain amount of money and offers an allocation of this amount to a responder. If the responder accepts the offer, the amount is allocated as proposed; otherwise both players receive no money. In the present research, we were particularly interested in the responder decision to accept or reject low (unfair) offers. Many responders reject offers of 20% or less of the available amount (Camerer, 2003), a decision that is interpreted by most researchers as indicating a preference for being treated fairly (Fehr & Gächter, 2000).

Dual-process research in the ultimatum game

A large body of literature has investigated how intuitive versus reflective modes of processing affect responder decisions. Several studies have shown that adopting a reflective mode of processing increases the likelihood of accepting unfair offers, as compared to an intuitive mode (e.g., Grimm & Mengel, 2011; Sutter, Kocher, & Strauß, 2003). On the other hand, there are also studies with opposite results, demonstrating that unfair offers are less likely to be accepted in a reflective than intuitive mode of processing (e.g.,
Hochman, Ayal, & Ariely, 2015; Knoch et al., 2008). This research demonstrates that adopting different modes of processing has consequences for the decision to accept or reject unfair offers, although the nature of these consequences remains puzzling.

**The experiment**

In a screening session conducted one week prior to the experiment, we assessed participants’ social value orientation (SVO; Messick & McClintock, 1968; Murphy & Ackermann, 2014; van Lange, 1999), a simple measure of social preferences that is probably related to the decision to accept or reject unfair offers in the ultimatum game. SVO captures preferences for allocating resources between oneself and another person. High versus low SVO scores correspond to prosocial versus selfish preferences, respectively. In the experimental session participants made an if-then plan to adopt an intuitive (“If I start pondering at length, then I will tell myself: ‘Listen to your guts!’”) or a reflective (“If I start acting in a hasty way, then I will tell myself: ‘Use your brain!’”) mode of processing (intuitive and reflective condition, respectively), or made no such plans (control condition) before deciding to accept or reject a series of 10 ultimatum offers including very low (unfair) ones.

Before they started specifying their if-then plans, participants in the intuitive and the reflective condition were instructed to think about pondering at length and acting in a hasty way, respectively, as potential obstacles for achieving their goals in the ultimatum game (i.e., mental contrasting Oettingen, Pak, & Schnetter, 2001). Such a “mental contrasting with implementation intentions” strategy (MCII; Oettingen, 2012; Oettingen, Wittchen, & Gollwitzer, 2013) facilitates the effects of if-then planning.

**The effects of strategically regulated information processing on responder decisions**

Our questionnaire data indicate that people understood the respective mode of processing plans and were willing to act upon them. This conclusion was further corroborated by a response time analysis which revealed that participants in the reflective condition responded more slowly to unfair offers than those in the intuitive condition, whereas no such difference evinced for fair offers. This result highlights the specificity of the if-then planning effects on information processing, as unfair—but not fair—offers should pose a conflict between acceptance and rejection decisions and thus might give raise to the obstacles of finding oneself pondering at length or acting hastily.
To investigate the effects of if-then planning on decision making, we analyzed responses to the ultimatum offers. We observed that participants in the reflective condition were more likely to accept unfair offers than those in the intuitive condition. Interestingly, this effect was further qualified by an interaction effect of condition and SVO, indicating that the effect of adopting an intuitive versus a reflective mode of processing was larger for higher (i.e., more prosocial) SVO scores. Specifically, prosocial individuals accepted more unfair offers in a reflective than an intuitive mode of processing, whereas selfish individuals accepted rather high shares of unfair offers irrespective of how they processed information.

**Conclusion**

Research Paper III once more demonstrates that people can strategically regulate how they process information. Participants in the present study planned to adopt a certain mode of processing, and the response time analysis indicates that successfully acted on these plans. This is an intriguing generalization of the first two research papers, as people directly planned to engage in a processing mode (rather than regulating information processing by planning a specific response), and the focus was on intuitive versus reflective rather than efficient information processing.

Importantly, the third research paper sheds light on the consequences of self-regulated information processing. It demonstrates that strategically engaging in intuitive versus reflective information processing has important consequences for decisions, in the present case affecting the decision to accept or reject unfair ultimatum offers. Moreover, it reveals social value orientation as a moderator of these effects: for prosocials, but not for selfish people, the decision to accept or reject unfair offers hinged on whether they planned to engage in an intuitive or a reflective mode of processing.

**General Discussion**

The three research papers reported in the present thesis demonstrate that people can strategically self-regulate how they process information using if-then plans, and it presents an example for how doing so affects preference-based decision making. In what follows, I will discuss implications of these findings for research on if-then planning as well as for research on information processing and decision making, and I will sketch potential routes of future research.
Implications

The present research has several implications, many of them already detailed in the research papers. In this section I will start by highlighting the implications for research on the self-regulation strategy of if-then planning and then proceed to implications for research on information processing and decision making.

Implication for research on if-then planning

The findings reported in the current thesis corroborate and advance prior research on if-then planning first by demonstrating and scrutinizing the effects of making if-then plans on information processing. Research Papers I and II provide initial evidence showing that people can strategically regulate various aspects of how efficiently they process information with if-then plans, explaining the various beneficial effects of if-then planning on goal attainment (Gollwitzer & Sheeran, 2006) even when these goals involve the regulation of automatic cognitive processes. Beyond this observation, the second research paper also reveals that task complexity might determine which aspect of enhanced information processing is a key determinant of if-then planning effects (e.g., perceptual processing and/or attentional selectivity). Taken together, the current thesis provides novel and intriguing insights into the processes underlying if-then planning.

As second implication pertains to recent efforts to integrate the concept of if-then planning into an interdisciplinary framework (e.g., physiological approaches; Wieber et al., 2015). As an illustration, consider the second research paper. It rests on a sequential sampling approach to information processing, which is an extensively used approach in many fields of experimental psychology, such as cognitive psychology and neuroscience (e.g., Gold & Shadlen, 2007; Heekeren, Marrett, & Ungerleider, 2008; Ratcliff, Gomez, & McKoon, 2004; P. L. Smith & Ratcliff, 2004; Voss, Nagler, & Lerche, 2013). The study relates the effects of making if-then plans to more efficient processing, as indicated by an increased drift rate. As a consequence, if-then planning effects can be described in terms of sequential sampling models, and thus be grasped by audiences that are familiar with the concepts underlying these models. This facilitates the development of an interdisciplinary perspective on if-then planning as a self-regulation strategy.

Finally, past research on if-then planning has limited itself to studying situations in which a specific instrumental goal-directed response could be anticipated and then be specified in the then-part of a respective if-then plan (such as those used in the first two research papers). Research Paper III ex-
General Discussion

pands this research, demonstrating that if-then planning can as well be used

to link situations to intuitive versus reflective modes of information process-

ing in general. Similar to responses commonly used in if-then plans, the

planned mode of processing was initiated only when the specified situation

was encountered, indicating a high degree of specificity. Thus, if-then plan-

ning can be used to encourage intuitive versus reflective modes of processing

in an opportune situation, thereby liberating individuals from the necessity

of selecting specific instrumental responses in advance.

Implications for research on information processing and decision

making.

Besides its implications for research on if-then planning, the research reported

in the present thesis also yields novel and intriguing insights for research on

information processing and decision making. First, it demonstrates that peo-

ple can exert strategic control over how they efficiently process information.

To illustrate the impact of this finding, it is important to notice that the

efficiency of information processing is commonly considered to reach beyond

peoples’ control (e.g., Heitz, 2014; Luce, 1986). Accordingly, the drift rate pa-

rameter in sequential sampling models—representing processing efficiency—

has so far usually been treated as an exogenous variable which primarily

captures task difficulty (e.g., Ratcliff, 2002; Ratcliff et al., 2004) or stable

individual differences (e.g., working memory and intelligence; Schmiedek,

Oberauer, Wilhelm, Süss, & Wittmann, 2007; van Ravenzwaaij, Brown, &

Wagenmakers, 2011). Our research suggests that this assumption needs to

be revised. Analogously, research on dual-process models has not yet con-

sidered the possibility that people may strategically switch between intuitive

and reflective modes of processing when making decisions, and has rather

focused on momentary fluctuations regarding which mode prevails (e.g., De

Neys, 2014; Hofmann, Friese, & Strack, 2009). Consequently, the present

thesis paves the way for understanding human information processing as a

matter of strategic control.

Second, the present research introduces if-then planning as a general tool
to study information processing and decision making. The effects of if-then
planning on information processing were observed irrespective of whether we
induced the plans via the task design (Research Paper I), instructed partici-
pants to make plans for specific situations (Research Paper II), or augmented
the plans with a mental contrasting strategy (Research Paper III). Moreover,
the planned response could be either a specific behavior (e.g., pressing a but-
ton) or a general mode of processing (e.g., relying on gut feelings); while the
situation could be an external stimulus (e.g., the number 2) or a subjective
state of affairs (e.g., acting hastily). As I have argued with my colleagues elsewhere (Martiny-Huenger, Bieleke, & Gollwitzer, in preparation), if-then planning exploits basic mechanisms of human action control and can thus flexibly be used as a self-regulation strategy. The consistent pattern of results across the studies presented in this theses further attests to the robustness and generalizability of if-then planning effects on information processing and decision making.

Future Directions

The present thesis is a first step in understanding humans’ general capability to and the consequences of self-regulated information processing. I see several possible future directions for research on this topic, and I will outline two of the most striking ones. The first direction pertains to bringing together research related to perceptual and preference-based decision making, while the second one is concerned with understanding the implementation and scope of self-regulated information processing.

Perceptual versus preference-based decisions

The present thesis is essentially split into two parts; the first one is concerned with how if-then planning affects information processing using methods from cognitive psychology, whereas the second one focuses on the effects of planned information processing on decision making from the perspective of behavioral economics. Whereas this multi-method approach allowed to investigate both questions within specialized fields, it remains silent regarding the association between both approaches. After all, what does it mean for responses to unfair offers that if-then planning changes how efficiently people process information about simple perceptual stimuli?

This is not a trivial question, and an exhaustive treatment of this topic reaches well beyond the scope of the present thesis. That said, I shall point to emerging evidence indicating that both simple perceptual and preference-based decisions might be governed by common principles of information processing (e.g., Fehr & Rangel, 2010; Oppenheimer & Kelso, 2015; Summerfield & Tsetsos, 2012). Most notably, sequential sampling models—like the one used in the present thesis—make sensible predictions not only for perceptual decisions, they also capture important characteristics of preference-based decision making (e.g., Krajbich, Oud, & Fehr, 2014; Milosavljevic, Malmaud, Huth, Koch, & Rangel, 2010), such as simple purchase decisions (Krajbich, Lu, Camerer, & Rangel, 2012) or food choices (Krajbich, Armel, & Rangel, 2010). Although still in its infancy, this research might be taken to indicate
that if-then planning enables people to strategically regulate central characteristics of information processing (e.g., the efficiency of evidence accumulation), with effects that might generalize to perceptual and preferences-based domains of decision making.

Implementation and scope of self-regulated information processing

Research Paper III of the present thesis has demonstrated meaningful effects of planning to engage in intuitive versus reflective information processing on overt responses to unfair ultimatum offers, an example for preference-based decision making. However, this study did not provide insights into exactly how people implemented their plans to engage in one or the other processing mode. After all, the if-then plans did not entail a specific response, leaving it to the individual to behave in a way considered to be consistent with intuitive versus reflective processing. They could have implemented their plans, for instance, by attending differently to the available information, or by weighing pieces of information in a different manner. These issues could be studied with process tracing tools, such as eye-tracking (Duchowski, 2007) or mouselab (Payne, Bettman, & Johnson, 1988), which have been invaluable for understanding how people make their decisions (Glöckner & Witteman, 2010). Gaining insights into how people implement planned modes of processing is a fundamental issue, as it allows a better understanding of the general human capability to strategically regulate information processing.

Besides understanding how people implement their plans to engage in intuitive versus reflective processing, it is also interesting to investigate the consequences of such information processing plans across different domains of decision making. Among several questions certainly worth studying, an intriguing one pertains to domains in which people commonly struggle with engaging in reflective processing, although doing so would likely facilitate their goal attainment. Can people use if-then plans to initiate reflective processing in such situations? Colleagues of mine have recently started to address this question, studying whether planning to engage in reflective processing facilitates iterative reasoning in a guessing game (Dohmen, Gollwitzer, Fischbacher, & Oettingen, 2015) and reliance on objective information in investment games (Doerflinger, Martiny-Huenger, & Gollwitzer, 2015). The preliminary results are promising, as they indicate that people can indeed initiate reflective information processing even in these challenging cases. Research along these lines thereby shed light on the scope of self-regulated information processing with regard to facilitating decision making.
Summary and Conclusion

The present research investigated whether people can strategically regulate their information processing, and the effects of such strategic information processing on decision making, using the self-regulatory strategy of if-then planning. In the first two research papers, making if-then plans enabled people to enhance the efficiency of processing sensory information, resulting in faster responses without drops in accuracy. In the third research paper, planning to engage in intuitive versus reflective information processing altered responses to unfair ultimatum offers, an example for preference-based decision making. Taken together, these results suggest that people can strategically regulate how they process information with if-then plans, and this control has meaningful consequences for their decisions. This demonstration advances our understanding of if-then planning as a self-regulatory strategy. Furthermore, it provides a novel perspective that conceives of human information processing and decision making as a matter of strategic regulation.
Research Paper I

The Benefit of no Choice: Goal-directed Plans Enhance Perceptual Processing

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Abstract

Choosing among different options is costly. Typically, response times are slower if participants can choose between several alternatives (free-choice) compared to when a stimulus determines a single correct response (forced-choice). This performance difference is commonly attributed to additional cognitive processing in free-choice tasks, which require time-consuming decisions between response options. Alternatively, the forced-choice advantage might result from facilitated perceptual processing, a prediction derived from the framework of implementation intentions. This hypothesis was tested in three experiments. Experiments 1 and 2 were PRP experiments and showed the expected underadditive interaction of the SOA manipulation and task type, pointing to a pre-central perceptual origin of the performance difference. Using the additive-factors logic, Experiment 3 further supported this view. We discuss the findings in the light of alternative accounts and offer potential mechanisms underlying performance differences in forced- and free-choice tasks.
Introduction

Deciding between different options is often difficult, particularly when all alternatives have similar advantages and disadvantages. Not only may one be losing some nerves—such decisions also consume time. Berlyne (1957a) was the first to demonstrate this by contrasting “polar” with “arbitrary decisions.” To do so, he used *forced-choice* and *free-choice tasks*. In general, two stimuli were mapped onto two distinct responses in these experiments. In forced-choice trials, one stimulus appeared and required the corresponding response. In free-choice trials, both stimuli appeared and participants were to decide by themselves which response to give. Free-choice latencies were consistently longer than forced-choice latencies and tasks of these types (and some variants) have subsequently been used in a variety of studies (Elsner & Hommel, 2001; Gaschler & Nattkemper, 2012; Herwig, Prinz, & Waszak, 2007; Janczyk, Heinemann, & Pfister, 2012; Janczyk, Nolden, & Jolicoeur, 2015; Pfister, Kiesel, & Hoffmann, 2011; Pfister, Kiesel, & Melcher, 2010). Currently, forced- and free-choice tasks are typically employed to study putatively different types of actions labeled either “externally triggered,” “stimulus-based,” etc., or “internally generated,” “voluntary,” etc. (Brass & Haggard, 2008; Gaschler & Nattkemper, 2012; Herwig et al., 2007; Janczyk et al., 2012; Passingham, Bengtsson, & Lau, 2010; Pfister et al., 2011, 2010).

What is the cause of the longer latencies in the free-choice compared to the forced-choice task? At first glance, and especially when considering the context in which these tasks are used in current research, it seems that the free-choice task requires more or more complex decisions, in particular concerning *what* response to give (see the what-when-whether model; Brass & Haggard, 2008). For example, deciding between three options takes longer than between only two options in a forced-choice task—and this additional processing appears to emerge from a central processing stage that is often associated with response selection (van Selst & Jolicoeur, 1997).

Although this reasoning is appealing, other sources for the latency difference are possible. In the next section we argue that differences in perceptual processing present themselves as a viable additional explanation.¹ Subsequently, we introduce the particular experimental paradigm used in this study to disclose the perceptual nature of the latency difference.

¹Note that Berlyne (1957a, 1957b) has already speculated about why participants do respond at all in free-choice tasks and why the respective RTs are longer than in forced-choice tasks. Briefly, he alluded to the idea of enhanced response competition in the case of free-choice tasks where no clear stimulus-induced bias exists. We return to this interpretation in the General Discussion and relate it to the present findings.
The Facilitating Effects of Plans for Goal Achievement

Consider the case where participants have a set of two button press responses for three stimuli. Two of the stimuli are associated with a specified key (forced-choice). The third stimulus is not uniquely mapped to a particular key press (free-choice). Hence, both tasks do not differ, for example, in terms of response set size. As even simply pressing a response key can be conceived as a goal (Prinz, 1998) both tasks also have the same goal—namely, to press a key as asked for by the experimenter in the instructions. A difference is, however, that only the forced-choice task imposes an unambiguous link between environmental events and behavior that is instrumental for attaining the goal. Moreover, the instructions commonly used in forced-choice tasks explicitly describe this link in order to explain the task (e.g., if an X appears, then press the left key). In contrast, instructions for free-choice tasks usually do not describe such a link as they emphasize the parity of the possible responses (e.g., try to press both keys about equally often).

Forced-choice tasks thus differ from free-choice tasks in that they involve the formation of if-then plans linking the relevant stimuli to corresponding responses. The effects of such if-then plans on action control have been described by the theory of implementation intentions (Gollwitzer, 1993, 1999). Specifically, the theory asserts that having a goal (“I intend to achieve goal G!”) is just a first step for successful goal attainment (the goal intention). The second step comprises the formation of a particular plan on how to achieve this goal successfully (the implementation intention), which is subordinate to and working toward the goal intention. Such plans specify a critical goal-relevant situational cue (the stimulus) and link it to an instrumental goal-directed behavior (the response), for example “If situation S occurs, then I will perform behavior B!” A meta-analysis (Gollwitzer & Sheeran, 2006) has illustrated the importance of if-then planning beyond mere goal setting by showing a medium-to-large effect size ($d = 0.65$) of implementation intentions on the rate of goal attainment.

As a consequence, forced-choice tasks are characterized by the additional effects on action control permitted by if-then planning.\(^2\) This im-

\(^2\)Of course, individuals could spontaneously (i.e., without explicit instruction) conceive free choices as stimulus-response links like “if an X appears, then I press the left key about half of the times.” However, research indicates that most individuals substantially benefit from the explicit instruction to use such stimulus-response links (for review, see Gollwitzer & Sheeran, 2006), suggesting that spontaneous planning does not play a critical role. Further, implementation intentions are the more effective the more clearly defined the linked behavior in the “then”-part is (Gollwitzer, 1993; Gollwitzer, Wieber, Meyers, & McCrea, 2010). The definiteness of the if-then plan is necessarily higher for forced- than for free-choice tasks in setups like the present study. Thus, one might in fact speak of
plies that forced-choice tasks evoke the same cognitive processes that have been found to mediate the effects of implementation intentions: heightened stimulus accessibility and automated response initiation (Gollwitzer, 1999; Parks-Stamm, Gollwitzer, & Oettingen, 2007; Webb & Sheeran, 2007). Specifically, forming an implementation intention allows responding immediately (Gollwitzer & Brandstätter, 1997; Orbell & Sheeran, 2000), efficiently (Brandstätter et al., 2001; Lengfelder & Gollwitzer, 2001), and without conscious intent (Bayer et al., 2009) as soon as a critical stimulus is detected in the environment.

Accessibility of a critical stimulus is facilitated by implementation intentions because the cognitive representation of this stimulus becomes highly activated. For instance, Aarts et al. (1999) instructed participants to form implementation intentions in an initial task. In an allegedly unrelated lexical decision task conducted afterwards, the authors observed faster categorization of words related to the if-part of this implementation intention compared to unrelated words. A study by Webb and Sheeran (2007) combined the lexical decision task with a sequential priming paradigm. Participants with an implementation intention were found to be faster in categorizing words related to the stimulus that was pre-activated by subliminal presentation. Similarly, Bayer et al. (2009) showed that a subliminal presentation of the stimulus is sufficient for facilitating response preparation and initiation.

Attentional and Perceptual Processing

The heightened activation of the stimulus specified in the if-part of an implementation intention appears to enhance early attentional processes, such as sensory filtering, that manifest themselves in facilitated perceptual processing. Recent theories of selective attention distinguish these early attentional processes from later stages of attentional selectivity (e.g., the dual-stage two-phase model; Hübner et al., 2010). While the late stage is based on categorical processing of a selected stimulus component, the early stage essentially reflects a sensory filter that enhances or attenuates the impact of stimulus features. In the domain of visual perception, for example, this filter is often described as a spotlight that can be allocated to a certain spatial location. Items at that location are then processed more intensively than items at other positions (Posner, 1980; Posner, Snyder, & Davidson, 1980). Action control benefits from this early filtering because relevant features of the sensory in-
put are prioritized over irrelevant information. Early filtering, however, is generally susceptible to irrelevant information and therefore imperfect, but it can benefit from the allocation of additional resources.

In fact, there is evidence that implementation intentions (as fostered in forced-choice tasks) improve early attentional filtering of relevant information by increasing the accessibility of a particular critical stimulus. For example, Wieber and Sassenberg (2006) used neutral words and words related to the stimulus specified in an implementation intention as distracters in a flanker task. The task was to categorize a word presented between these distracters as fast as possible. Consistent with the assertion of enhanced sensory processing of the stimulus specified in an if-then plan, the authors found impaired performance in trials using the stimulus-related words as distracters. In a subsequent study, Achtziger et al. (2012) employed a dichotic listening task and asked participants to repeat words presented to the attended channel. Corroborating the above interpretation, task performance was significantly impaired by simultaneously presenting stimulus-related words to the unattended channel. Finally, fits of a computational sequential sampling model (Hubner et al., 2010) to data from a flanker task revealed that implementation intentions improve early attentional processes (Bieleke, Dambacher, Hubner, & Gollwitzer, 2015). Hence, there is evidence that if-then plans provide an early attentional advantage for the stimulus specified in the if-part, and therefore enhance the efficiency of its perceptual processing. Given that forced-choice tasks involve the formation of such plans, it is possible that performance differences between forced- and free-choice tasks have a perceptual source.

Pinpointing the Advantage of Forced-choice Tasks

To examine the perceptual contribution to the performance difference between forced- and free-choice tasks, we employed a well-established chronometric method to specify the locus of experimental effects: the Psychological Refractory Period (PRP) paradigm (Pashler, 1994; Telford, 1931) and the locus-of-slack logic (Schweickert, 1978). The PRP paradigm is a dual-task paradigm where participants work on two tasks on each trial. Both tasks have their own stimuli (S1 and S2) and responses (R1 and R2). The time between onset of S1 and S2, the stimulus onset asynchrony (SOA), is experimentally varied. While response times in Task 1 (RT1) are more or less independent of the SOA, those in Task 2 (RT2) sharply increase with shorter SOAs. One widely accepted account for this PRP effect is the central bottleneck model (Pashler, 1994; Welford, 1952) that divides task processing into three stages (see Figure 1): (1) a pre-central, perceptual stage; (2) a
central stage of response selection; and (3) a post-central, motor stage. The crucial assumption is that only one central stage can be processed at any time, hence generating a central bottleneck. In contrast, different pre- and post-central operations can run in parallel with all other stages. With a short SOA, perceptual processing in Task 2 is finished while the central stage of Task 1 is still running. Thus, processing of the central stage in Task 2 must be postponed until central processing in Task 1 is finished. The emerging idle time is called the cognitive slack and is responsible for the increased RT2. With longer SOAs such a cognitive slack becomes less likely, and RT2 becomes shorter.

Turning this logic around, the PRP paradigm can be used to localize the emergence of experimental effects (e.g., Janczyk, 2013; Kunde, Pfister, & Janczyk, 2012; J. Miller & Reynolds, 2003; Schweickert, 1978). When using the locus-of-slate logic, the manipulation of interest is implemented in Task 2. Then, the diagnostic result relates to the interaction of this manipulation with the SOA. If the manipulation affects (i.e., prolongs) the pre-central stage of processing, two scenarios occur (see Figure 1 for an illustration): at short SOAs, the additional processing time stretches into the cognitive slack and as a consequence RT2 does not increase. At long SOAs, however, no slack exists and the additional pre-central processing also delays subsequent processing, giving rise to an increased RT2. Statistically, this pattern results in an underadditive interaction of the manipulation of interest and SOA. In fact, manipulations affecting perceptual characteristics, such as stimulus intensity or contrast, combined underadditively with SOA in several studies (e.g., Pashler, 1984; Pashler & Johnston, 1989). If instead the manipulation affects the central or post-central stage, the additional processing time cannot be absorbed into the slack and RT2 should increase independent from SOAs. Hence, SOA and the manipulation should not interact, but combine additively. In sum, facilitated perceptual processing in forced- compared to free-choice trials should manifest as an underadditive interaction between SOA and task type in this paradigm.

The Present Study

Based on this rationale, we varied forced- and free-choice tasks as Task 2 in two PRP experiments. Experiment 1 was designed after the classical experiments of Berlyne (1957a). In Experiment 2 we used a different version of both task variants to circumvent a potential confound in Experiment 1. The PRP paradigm then permits a straightforward test of the reasons for reduced response times in forced- compared with free-choice tasks: Because if-then plans are formed in the forced-choice task only, we expect to observe
Figure 1. (a) Illustration of the PRP paradigm. The critical assumption is that the central stage of processing (B) represents a processing bottleneck, while perceptual (A) and motor (C) processes can run in parallel to other stages. At short stimulus onset asynchronies (SOAs), processing of the Task 2 central stage (B2) must await release of this bottleneck from Task 1 central processing (B1) leading to some idle time (called the cognitive slack) and increased RT2s. At long SOAs no idle time occurs and RT2s are accordingly lower. (b) Illustration of the locus-of-slack logic. If a manipulation M affects and prolongs Task 2 perceptual processing (A2), the additional time stretches into the cognitive slack at short but not at long SOAs. Thus the effect becomes only visible at the long SOAs resulting in an underadditive interaction of SOA and the manipulation M. Importantly, a manipulation M affecting later stages prolongs RT2 to the same degree irrespective of SOA.
facilitated perceptual processing as indicated by an underadditive interaction of SOA and the forced- vs. free-choice manipulation. Using the additive-factors logic (Sternberg, 1969), Experiment 3 complements the results from the first two experiments by manipulating stimulus contrast as a determinant of perceptual processing. These data also address an alternative account for an underadditive interaction in the PRP experiments.

**Experiment 1**

Experiment 1 was designed after Berlyne’s (1957a) experiments. Stimuli were two letters in three different colors. In Task 1, participants responded to the letter identity, while in Task 2, they responded to the letter color. Two colors were mapped to a particular response (forced-choice), while the third color was not associated with a particular response (free-choice). Two versions of this experiment were conducted, differing with regard to the levels of SOA (Experiment 1a: two levels; Experiment 1b: three levels). Because forced-choice tasks involve the formation of if-then plans, we predict an underadditive interaction of task type (forced-choice vs. free-choice) and SOA. In other words, the RT difference between both task types should be evident at long SOAs but not at short SOAs. In contrast, no significant interaction is expected if the RT difference is located in post-perceptual processes.

**Method**

**Participants**

Twelve participants took part in Experiment 1a (10 females, mean age 25.2 years) and another group of 24 participants took part in Experiment 1b (19 females, mean age 22.2 years). Participants were naïve regarding the hypotheses of the experiment, received course credit or monetary compensation, and reported normal or corrected-to-normal vision.

**Apparatus and stimuli**

Experimental procedures were controlled by a standard PC connected to a 17 in. CRT monitor. The background was black. Stimuli were the letters X and S. They were first presented in grey color and their identity was S1. In the course of the trial they changed their color to green, red, or yellow.

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3In Berlyne’s 1957a experiments both (forced-choice) stimuli were presented in a free-choice trial.
and these colors served as S2. Responses were collected via external custom-built keys. Two keys were located to the left of the participants, allowing them to execute R1 with the left index- and middle-finger. Two other keys were located to their right, in order to execute R2 with the right index- and middle-finger.

Tasks and procedure

Task 1 required participants to respond to the identity of the letter (S1), whereas Task 2 required them to respond to their color (S2). Two of the possible colors were mapped to a specific R2 (forced-choice task). The third color was the stimulus for the free-choice task and no particular response was prescribed (free-choice).

A trial started with the presentation of a fixation cross (500 ms) followed by a blank screen (500 ms). Then, the letter appeared (S1) and following a variable stimulus onset asynchrony (SOA), the letter took a different color (S2). In case of errors, feedback was given for 1000 ms. In Experiment 1a, the SOAs were either 50 or 1000 ms; in Experiment 1b they were 50, 300, or 1000 ms. In Experiment 1a, each block comprised 60 trials; that is, five repetitions of all combinations resulting from the 2 S1 (X vs. S) \times 3 S2 (green vs. red vs. yellow) \times 2 SOAs (50 vs. 1000 ms) design. In Experiment 1b, each block comprised 90 trials because of the additional 300 ms SOA.\footnote{Due to a programming error, participants 1-16 of Experiment 1b had only 85 instead of 90 trials per block.} The experiments consisted of five blocks, preceded by an unanalyzed practice block.

Instructions were given in written form prior to the experiment and emphasized response speed and accuracy. As it is common for forced-choice tasks, the instructions for the forced-choice stimuli explicitly mentioned the stimulus-response link in an if-then format (e.g., “If the stimulus turns red, then press the left key!”). Conforming to common standards for free-choice tasks, the instructions for the free-choice stimulus mentioned no particular response, but participants were encouraged to avoid any strategies and to press both keys about equally often. Priority was given to Task 1. The mapping of stimuli to tasks (forced- vs. free-choice) and to responses for the forced-choice task were counterbalanced across participants.

Design and analyses

Trials with general errors (no response, R2s later than 4,000 ms after S2 onset, response prior to stimulus onset, R2 prior to R1) were excluded. For RT
analyses, only trials with correct R1 and R2 were considered. Further, RTs deviating more than 2.5 standard deviations from the mean (calculated separately for each participant and condition) were excluded as outliers. Mean RTs and mean percentages of errors (PE) of Task 1 were submitted to an analysis of variance (ANOVA) with task type (forced-choice vs. free-choice) and SOA (Experiment 1a: 50 vs. 1000 ms, Experiment 1b: 50 vs. 300 vs. 1000 ms) as repeated measures. As it was not possible to give erroneous responses in Task 2 for a free-choice trial, PE2s were evaluated by an ANOVA with SOA as a single repeated measure. We further analyzed the percentage of Task 2 free-choice trials in which participants repeated the response of Task 1 in Task 2. These percentages were subjected to an ANOVA with SOA (1a: 50 vs. 1000 ms; 1b: 50 vs. 300 vs. 1000 ms) as a repeated measure. A significance level of $\alpha = 0.05$ was adopted, and Greenhouse-Geisser corrected degrees of freedom were used when the sphericity assumption was violated. We report uncorrected degrees of freedom together with the $\epsilon$-estimate in these cases.

Results

Experiment 1a

Mean RT2s (2.6% outliers) are visualized in Figure 2 (left panel; see also Table 1). Clearly, responses were faster at the long than at the short SOA, the PRP effect, $F(1,11) = 116.51, p < 0.001, \eta_p^2 = 0.91$. Descriptively, they were also faster for the forced-choice than for the free-choice task, though not statistically significant, $F(1,11) = 3.02, p = 0.110, \eta_p^2 = 0.22$. However, the difference was larger at the long than at the short SOA, resulting in an underadditive interaction, $F(1,11) = 11.02, p = 0.007, \eta_p^2 = 0.50$. Specifically, RT2 was significantly shorter in the forced- than in the free-choice task only at the long SOA, $t(11) = 2.90, p = 0.014, d = 1.18$. Mean PE2s are summarized in Table 1 and did not reliably differ across SOAs, $F(1,11) = 0.59, p = 0.460, \eta_p^2 = 0.05$. In the free-choice task, participants pressed the left key in 58.2 and 55.6% of the trials at the SOAs of 50 and 1000 ms. Three participants pressed one response key in < 20%, but their exclusion did not change the critical results. Participants repeated the Task 1 response in a free-choice trial in 54.5 and 49.9% of the trials at the SOAs of 50 and 1000 ms, respectively, $F(1,11) = 3.78, p = 0.078, \eta_p^2 = 0.26$.

Mean RT1 (2.6% outliers) and PE1s are summarized in Table 1. Responses were faster at the long compared to the short SOA, $F(1,11) = 14.44, p = 0.003, \eta_p^2 = 0.57$. No other effect was significant, task type: $F(1,11) = 1.29, p = 0.280, \eta_p^2 = 0.10$, interaction: $F(1,11) = 0.19, p = 0.671,$
Figure 2. Mean response times in Task 2 (RT2) as a function of task type and stimulus onset asynchrony (SOA). Asterisks mark a pairwise difference at $p \leq 0.05$ (two-tailed).

$\eta^2_p = 0.02$. PE1s showed little variation and no effect was significant, SOA: $F(1, 11) = 0.34, p = 0.573, \eta^2_p = 0.03$, task type: $F(1, 11) = 0.01, p = 0.944$, $\eta^2_p < 0.01$, interaction: $F(1, 11) = 1.89, p = 0.196, \eta^2_p = 0.15$.

Experiment 1b

Mean RT2s (2.9% outliers) are visualized in Figure2 (right panel; see also Table 1) and replicate the pattern from Experiment 1a. Clearly, a PRP effect was evident, $F(2, 46) = 183.40, p < 0.001, \eta^2_p = 0.89, \epsilon = 0.65$, and responses again tended to be faster in the forced-choice than in the free-choice task, $F(1, 23) = 3.25, p = 0.085, \eta^2_p = 0.12$. The difference was the largest and significant at the longest SOA, $t(23) = 5.06, p < 0.001, d = 1.46$, resulting in an underadditive interaction, $F(2, 46) = 6.68, p = 0.003, \eta^2_p = 0.23$. Mean PE2s are summarized in Table 1 and did not differ between SOAs, $F(2, 46) = 0.59, p = 0.505, \eta^2_p = 0.02, \epsilon = 0.71$. In the free-choice task, participants pressed the left key in 57.3, 54.9, and 48.7% of the trials at the SOAs of 50, 300, and 1000 ms. Two participants pressed one response key in < 20%, but their exclusion did not change the critical results. Participants repeated the Task 1 response in the free-choice task in 52.4, 51.0, and 48.8% of the trials at the SOAs of 50, 300, and 1000 ms, respectively, $F(2, 46) = 0.50, p = 0.563, \eta^2_p = 0.02, \epsilon = 0.76$. 
Experiment 1

Table 1. Mean response times in Tasks 1 and 2 (RT1, RT2) and mean error percentages in Tasks 1 and 2 (PE1, PE2) as a function of task type and stimulus onset asynchrony (SOA).

<table>
<thead>
<tr>
<th>Task type</th>
<th>Experiment 1a</th>
<th></th>
<th>Experiment 1b</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SOA (ms)</td>
<td></td>
<td>SOA (ms)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>50</td>
<td>1000</td>
<td>50</td>
<td>300</td>
</tr>
<tr>
<td>RT2 (ms)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Forced-choice</td>
<td>971</td>
<td>477</td>
<td>842</td>
<td>628</td>
</tr>
<tr>
<td>Free-choice</td>
<td>989</td>
<td>546</td>
<td>838</td>
<td>641</td>
</tr>
<tr>
<td>PE2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Forced-choice</td>
<td>5.2</td>
<td>6.0</td>
<td>6.3</td>
<td>6.5</td>
</tr>
<tr>
<td>RT1 (ms)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Forced-choice</td>
<td>730</td>
<td>623</td>
<td>657</td>
<td>640</td>
</tr>
<tr>
<td>Free-choice</td>
<td>713</td>
<td>597</td>
<td>645</td>
<td>642</td>
</tr>
<tr>
<td>PE1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Forced-choice</td>
<td>4.9</td>
<td>3.8</td>
<td>3.8</td>
<td>3.7</td>
</tr>
<tr>
<td>Free-choice</td>
<td>4.4</td>
<td>4.3</td>
<td>5.0</td>
<td>3.1</td>
</tr>
</tbody>
</table>

Mean RT1s (2.9% outliers) and mean PE1s in Task 1 are summarized in Table 1. RT1s were relatively constant and no effect was significant, SOA: $F(2,46) = 0.19$, $p = 0.758$, $\eta^2_p = 0.01$, $\epsilon = 0.73$, task type: $F(1,23) = 0.74$, $p = 0.399$, $\eta^2_p = 0.03$, interaction: $F(2,46) = 0.51$, $p = 0.606$, $\eta^2_p = 0.02$. Participants made less errors the longer the SOA, $F(2,46) = 7.85$, $p = 0.001$, $\eta^2_p = 0.25$. No other effect was significant, task type: $F(1,23) = 0.17$, $p = 0.685$, $\eta^2_p = 0.01$, interaction: $F(2,46) = 2.88$, $p = 0.066$, $\eta^2_p = 0.11$.

Discussion

The two versions of Experiment 1 provide converging results: the forced-vs. free-choice manipulation yielded visible RT2 differences only at the longest SOA. In other words, task type and SOA interacted underadditively. Interpreted in the framework of the PRP paradigm and the locus-of-slack logic (Schweickert, 1978), this result points to a pre-central source of the RT difference. The outcome is consistent with the predicted perceptual facilitation due to goal-directed if-then plans in forced-choice tasks, and thus provides
support for the notion of a perceptual locus of the forced-choice advantage. In Experiment 1a there was also an effect of SOA on RT1, a finding not uncommon in PRP experiments but not totally compatible with a bottleneck model (Pashler, 1994). A longer RT1 at short SOAs is more in line with a central capacity sharing model (Tombu & Jolicoeur, 2003). However, because we did not observe such pattern in Experiment 1b, and even the opposite pattern in Experiment 2 (see below), we refrain from drawing conclusions from this particular finding.

Although both Task 1 and 2 used the same sets of responses (left vs. right), the observed underadditivity was not due to more frequent, rapid response repetitions in the free-choice task at a short than at a long SOA. Yet, a potential disadvantage of this design is that forced- and free-choice trials appeared on two- and one-third of the trials, respectively (see Berlyne, 1957a, Experiments 2 and 3).\textsuperscript{5} Presenting both tasks equally often would, on the other hand, have resulted in unequal frequencies of S2 colors. In Experiment 2 we therefore used a different manipulation of task type, which granted both an equal number of forced- and free-choice trials and different response sets for Tasks 1 and 2. At the same time, this approach tested the generalizability of the results of Experiment 1.

**Experiment 2**

The task type manipulation was again implemented as Task 2 in a PRP experiment. In contrast to Experiment 1, however, we now used three different R2s. On each trial, either one particular R2 was required (forced-choice) or two R2s were suggested and participants chose freely between them (free-choice). Thus, both task types (as well as all stimuli and stimulus combinations) appeared equally often in the course of the experiment. As a further difference to Experiment 1, S1 was now an auditory stimulus. Our predictions were the same as in Experiment 1: an underadditive interaction of SOA and task type (forced-choice vs. free-choice).

**Method**

**Participants**

Twenty-four new participants performed in Experiment 2 (15 females, mean age 27.7 years) fulfilling the same criteria as those in Experiment 1.

\textsuperscript{5}At least in Experiment 3, Berlyne (1957a) doubled the free-choice trials for analyses to reach a comparable numbers of trials.
Apparatus and stimuli
S1 were two sinusoidal tones (300 and 900 Hz, 50 ms) presented via headphones. S2 were three horizontally arranged squares (1.5 \times 1.5 cm; 1.5 cm between squares). At the outset of a trial, only their white outlines were visible. In the course of a trial, one or two of the squares were filled white. Responses were collected via external custom-built keys. Two keys located to the left of the participants recorded R1 (left index- and middle-finger). Three other keys located to their right assessed R2 (right index-, middle-, and ring-finger).

Tasks and procedure
In Task 1, participants were to respond to the pitch of S1. In Task 2, in forced-choice trials, one square was filled white and the participants were instructed to press the corresponding key (i.e., left square \rightarrow index-finger, middle square \rightarrow middle-finger, right square \rightarrow ring-finger). In free-choice trials, two squares were filled white and participants freely chose between the corresponding two keys.

A trial started with the three unfilled squares. After 500 ms a tone (S1) was played and following a variable SOA of 50, 300, or 1000 ms one (forced-choice) or two (free-choice) squares turned white (S2). Each block comprised 72 trials; that is, two repetitions of all combinations resulting from the 2 S1 (300 vs. 900 Hz) \times 6 S2 (3 forced-choice stimuli and 3 free-choice stimuli) \times 3 SOAs (50 vs. 300 vs. 1000 ms) design in a random order. Each participant was first familiarized with the task in 20 randomly selected trials followed by a practice block. The main experiment consisted of five experimental blocks.

Written instructions were given prior to the experiment and emphasized response speed and accuracy. We again used the standard instructions for forced-choice stimuli that mention the explicit if-then plans (e.g., “If the left square becomes white, press the left key!”). For free-choice trials no particular response was mentioned. Participants were instructed to press one of the two possible keys if two squares turned white and they were further encouraged to avoid any strategies. The stimulus-response mapping in Task 1 was counterbalanced across participants.

Design and analyses
In general, analyses followed those of Experiment 1b. The main difference was that it was now possible to commit errors in the free-choice variant of Task 2. Thus, PE2s were submitted to the same ANOVA as RT2s.
Results

Mean RT2s are visualized in Figure 3 and mean RTs and PEs for both tasks are summarized in Table 2. The pattern of RT2 (2.7% outliers) closely resembles that observed in Experiment 1. RT2s decreased with an increasing SOA, $F(2, 46) = 446.56, p < 0.001, \eta^2_p = 0.95, \epsilon = 0.63$. Overall, responses were faster in the forced-choice than in the free-choice task, giving rise to a significant main effect of task type, $F(1, 23) = 12.31, p = 0.002, \eta^2_p = 0.35$. The difference was largest and significant at the longest SOA, $t(23) = 5.19, p < 0.001, d = 1.50$. Accordingly, the underadditive interaction was significant, $F(2, 46) = 4.93, p = 0.011, \eta^2_p = 0.18$. Participants committed less errors with an increasing SOA, $F(2, 46) = 13.90, p < 0.001, \eta^2_p = 0.38$, and they made more errors in the forced-choice task, $F(1, 23) = 14.21, p = 0.001, \eta^2_p = 0.38$. The interaction was not significant, $F(2, 46) = 2.42, p = 0.100, \eta^2_p = 0.10$. In the free-choice task, participants pressed the left, middle, and right key in 41.8, 34.6, and 23.7% of the trials at the SOA of 50 ms. The corresponding values for the SOA of 300 ms were 40.7, 35.2, and 24.2%, and for the SOA of 1000 ms 36.8, 38.7, and 24.5%. Two participants pressed one key in < 10%, but their exclusion did not change the critical results.

Mean RT1s (2.7%) increased with longer SOA, $F(2, 46) = 4.85, p = 0.023, \eta^2_p = 0.17, \epsilon = 0.72$. No other effect was significant, task type: $F(1, 23) = 0.61, p = 0.443, \eta^2_p = 0.03$, interaction: $F(2, 46) = 0.05, p = 0.953, \eta^2_p < 0.01$. Participants made less errors for longer SOAs, $F(2, 46) = 24.39, p < 0.001, \eta^2_p = 0.51$, and in free- compared to forced-choice trials, $F(1, 23) = 11.78,$
$p = 0.002, \eta_p^2 = 0.34$. The longest SOA revealed almost no difference, but the interaction of SOA and task type was significant, $F(2, 46) = 3.41, p = 0.042, \eta_p^2 = 0.13$.

Table 2. Mean response times in Tasks 1 and 2 (RT1, RT2) and mean error percentages in Tasks 1 and 2 (PE1, PE2) as a function of task type and stimulus onset asynchrony (SOA) in Experiment 2.

<table>
<thead>
<tr>
<th>Task type</th>
<th>SOA (ms)</th>
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<tbody>
<tr>
<td></td>
<td>50</td>
<td>300</td>
<td>1000</td>
<td></td>
</tr>
<tr>
<td>RT2 (ms)</td>
<td>Forced-choice</td>
<td>974</td>
<td>769</td>
<td>389</td>
</tr>
<tr>
<td></td>
<td>Free-choice</td>
<td>989</td>
<td>783</td>
<td>448</td>
</tr>
<tr>
<td>PE2</td>
<td>Forced-choice</td>
<td>5.2</td>
<td>3.4</td>
<td>1.9</td>
</tr>
<tr>
<td></td>
<td>Free-choice</td>
<td>2.6</td>
<td>2.2</td>
<td>0.8</td>
</tr>
<tr>
<td>RT1 (ms)</td>
<td>Forced-choice</td>
<td>778</td>
<td>814</td>
<td>792</td>
</tr>
<tr>
<td></td>
<td>Free-choice</td>
<td>784</td>
<td>822</td>
<td>795</td>
</tr>
<tr>
<td>PE1</td>
<td>Forced-choice</td>
<td>5.4</td>
<td>4.3</td>
<td>1.5</td>
</tr>
<tr>
<td></td>
<td>Free-choice</td>
<td>4.1</td>
<td>2.3</td>
<td>1.4</td>
</tr>
</tbody>
</table>

Discussion

The results from Experiment 2 are in accordance with those obtained in Experiment 1. Most importantly, task type again combined underadditively with SOA. This finding corroborates our previous conclusion that the RT difference between forced- and free-choice tasks has a pre-central source, and it is in line with the reasoning that if-then plans enhance perceptual efficiency (Achtziger et al., 2012; Bieleke et al., 2015; Wieber & Sassenberg, 2006). At the same time, participants made more errors in forced-choice trials. This result, however, is difficult to interpret as the probability to commit errors was higher in the forced-choice (two possible wrong responses) than in the free-choice task (only one possible wrong response). There was also an effect of task type on error rates in Task 1 similar to that in Task 2. While effects
on Task 1 are not uncommon in PRP studies, reasons for this particular result remain currently unknown. Note, however, that this effect does not undermine our conclusions.

**Experiment 3**

So far, the results from the present PRP experiments point to a pre-central source of the RT difference between forced- and free-choice tasks. This is in line with our reasoning that forced- but not free-choice tasks activate if-then plans that facilitate perceptual processing through early attentional advantages of critical stimuli (Achtziger et al., 2012; Bieleke et al., 2015; Wieber & Sassenberg, 2006).

While a pre-central locus has most often been conceptualized as perceptual processing, Hommel (1998) and Lien and Proctor (2002) suggested to subdivide the central stage of processing into response activation and response selection to explain backward-crosstalk effects. Response selection is seen as a bottleneck, but response activation is able to run in parallel with other processes. Hence, response activation could also be described as a pre-bottleneck stage and an underadditive interaction would be compatible with a locus in this stage. To further complement our conclusions, we used the additive-factors logic (Sternberg, 1969) in Experiment 3. According to this logic, two factors should interact if the underlying manipulations affect the same stage of processing. We therefore varied task type (as we did in Experiment 1) together with stimulus brightness—a factor known to affect perceptual processing. The straightforward prediction is an interaction of task type and stimulus brightness.

A similar experiment has been reported by Berlyne (1957a, Experiment 2) and the significant interaction revealed a larger brightness effect in forced-choice (1293 vs. 1105 ms; difference = 188 ms) than in free-choice trials (1478 vs. 1377 ms; difference = 101 ms; values for dark and bright stimuli, respectively). This result suggests a more critical role of perceptual processes in forced- than in free-choice tasks. Yet, the study is based on (16) 10-year-old participants and despite the significant interaction it is unclear whether the brightness manipulation affected forced- and free-choice trials when considered separately. Further, the results reported by Berlyne are not entirely compatible with related results from his own Experiment 1.

To clarify these issues—and particularly to examine whether there is an effect of brightness in free-choice trials or not—we ran Experiment 3 on a sample of 96 participants. To further promote perceptual processing in
the free-choice task, half of the participants were presented with free-choice stimuli that not only had a unique color, but also a unique form.

Method

Participants

Ninety-six participants took part in this experiment (70 females, mean age 24.6 years) and fulfilled the same criteria as in the previous experiments.

Apparatus and stimuli

Experimental procedures were controlled by a standard PC connected to a 17 in. CRT monitor. The background was black. Stimuli (S) in this experiment were green, red, and yellow squares, circles, and diamonds. Each stimulus had one of two brightness values (bright and dark). The bright stimuli were colored with full saturation; that is, the RGB values were (255, 0, 0) for the red, (0, 255, 0) for the green, and (255, 255, 0) for the yellow stimuli. These stimuli were edited using the GIMP software by lowering their saturation by 60/100 units. Stimuli were not checked for equiluminance, but importantly, their assignment to task types/responses was counterbalanced across participants (see below). Responses (R) were given with the left and right index-finger on the left and right CTRL-key on a standard keyboard.

Tasks and procedure

The task was to respond to the color of S. Two of the possible colors were mapped to a specific R (forced-choice task). The third color was the stimulus for the free-choice task. This assignment was independent of stimulus brightness. For one half of the participants, all stimuli were squares. To emphasize (perceptual) processing of the free-choice stimulus, it had a unique form for the other half of participants (diamonds or circles; and the other form for the forced-choice stimuli counterbalanced across these participants).

A trial started with the presentation of a fixation cross (250 ms) followed by a blank screen (cue-stimulus interval, CSI: 500 or 1000 ms). Then, the stimulus was presented until either R was given or 2500 ms had elapsed. In case of an error, feedback was displayed (1000 ms) and the next trial started after 1000 ms. Each block comprised 72 trials; that is, six repetitions of all combinations resulting from the 2 CSI (500 vs. 1000 ms) × 3 stimulus colors (green vs. red vs. yellow) × 2 brightness values (dark vs. bright) design. Participants performed 20 randomly selected familiarization trials followed
by an unanalyzed practice block. The main experiment consisted of six blocks.

Written instructions given prior to the experiment emphasized response speed and accuracy. For the forced-choice task, stimulus-response links were explicitly described in the instructions in an if-then format (e.g., “If the figure is red, then press the left key!”), but the shape was not mentioned. For the free-choice task, participants were encouraged to avoid any strategies and to choose both responses about equally often. The mapping of stimulus colors to tasks and of colors to responses within the forced-choice task was counterbalanced across participants.

Design and analyses

Trials with general errors (e.g., no response within 2500 ms after stimulus onset) were excluded. For RT analyses, only correct trials were considered and outliers were identified according to the same criterion as in the previous experiments. Three factors were of initial interest: task type (forced- vs. free-choice), brightness (bright vs. dark), and free-choice stimulus form (unique vs. not-unique). A preliminary ANOVA showed that the latter factor neither exhibited a main effect nor entered into any interaction, all $F$s < 1.94, all $p$s < 0.225. Thus, data were collapsed across this factor. Mean RTs were submitted to an ANOVA with task type and brightness as repeated measures. As no errors were possible in the free-choice task, PEs were only analyzed for the forced-choice task with brightness (bright vs. dark) as a repeated measure.

Results

Mean RTs (2.5% outliers) were 509 and 476 ms for the forced-choice task and 499 and 496 ms for the free-choice task (dark and bright stimuli, respectively; see also Figure 4). The ANOVA revealed that RTs were shorter for the bright than for the dark stimuli, $F(1,95) = 33.75$, $p < 0.001$, $\eta^2_p = 0.26$, but task type had no effect, $F(1,95) = 0.91$, $p = 0.344$, $\eta^2_p = 0.01$. Importantly, and as expected, the interaction was significant, $F(1,95) = 55.57$, $p < 0.001$, $\eta^2_p = 0.37$. A t test confirmed the typical RT advantage for forced-choice trials when stimuli were bright, $t(95) = 3.79$, $p < 0.001$, $d = 0.55$, but there was no significant difference for dark stimuli, $t(95) = 1.44$, $p = 0.153$, $d = 0.21$. Within the forced-choice task, RTs were faster for bright than for dark stimuli, $t(95) = 9.12$, $p < 0.001$, $d = 1.32$, whereas the difference was not significant in free-choice trials, $t(95) = 0.82$, $p = 0.416$, $d = 0.12$. This was true for both groups of participants, for those confronted with unique
forms, \( t(47) = 0.19, p = 0.849, d = 0.04 \), and for those confronted with non-unique forms, \( t(47) = 1.70, p = 0.095, d = 0.35 \). This confirms the visual impression of a marked brightness effect in forced-choice, but not in free-choice trials (Figure 4). In the free-choice tasks, participants pressed the left response key in 39.8% of the trials. Exclusion of 18 participants that pressed one response key in less than 20% of the trials led to the emergence of a main effect of task type, \( F(1, 77) = 6.97, p = 0.010, \eta^2_p = 0.08 \), because free-choice RTs were longer now. All other results including the pairwise t tests gave the same results. Finally, forced-choice trials entailed more errors with dark (7.6%) than with bright stimuli (5.1%), \( F(1, 95) = 35.94, p < 0.001, \eta^2_p = 0.27 \).

![Figure 4](image.png)

**Figure 4.** Mean response times (RT) in Experiment 3 as a function of task type and stimulus brightness. Asterisks mark a pairwise difference at \( p \leq 0.001 \) (two-tailed).

**Discussion**

According to the rationale of the additive-factors logic, the significant interaction of stimulus brightness and task type indicates that both manipulations affect the same stage of processing (Sternberg, 1969). Arguably, the most likely candidate is the perceptual stage (see Berlyne, 1957a, Experiment 2). Going beyond Berlyne’s study, the present data revealed no reliable influence of brightness on free-choices.

As in Experiment 1 and 2, the data are compatible with the idea that plans in the form of implementation intentions facilitate early perceptual pro-
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cessing (Achtziger et al., 2012; Bieleke et al., 2015; Gollwitzer, 1999; Wieber & Sassenberg, 2006). This not only corroborates the conclusions drawn from the PRP paradigm and the locus-of-slack logic (Pashler, 1994; Schweickert, 1978), but it also points to their generalizability.

General Discussion

Berlyne (1957a) was the first to report a latency difference between forced- and free-choice tasks, which have subsequently been employed in a variety of studies. At first glance, one may attribute the performance difference to additionally required, and time-costly, decisions in free-choice tasks. Yet, a careful analysis of the tasks also suggests a perceptual explanation: forced-choice tasks, but not free-choice tasks, involve using if-then plans that improve early attentional processes and hence facilitate perceptual processing of stimuli specified in the if-part.

Perceptual Facilitation in Forced-choice Tasks

Experiments 1 and 2 made use of the locus-of-slack logic in the PRP paradigm (Schweickert, 1978). Assuming a perceptual locus, the predicted underadditive interaction of SOA and task type was found in both experiments, despite different implementations of the tasks. Although the findings of Experiments 1 and 2 are in principle also compatible with an explanation in terms of response activation (Hommel, 1998; Lien & Proctor, 2002), several arguments support a perceptual source. First, in Experiment 3 the critical manipulation interacted with a perceptual factor and the same interaction was reported by Berlyne (1957a). Second, the theoretical derivations from evidence on implementation intentions explicitly point to a facilitation of perceptual processing. Third, recent work on computational modeling confirms that implementation intentions affect early perceptual filtering (Bieleke et al., 2015). In sum, the results give reason to assume that performance differences between forced- and free-choice tasks are—at least partly—due to facilitated perceptual processing rather than central (bottleneck) processes such as decision-making.

Conceivably, this has implications for the theoretical foundations of research based on forced- and free-choice tasks. As mentioned in the introduction, these tasks are currently often used to investigate a conceptual distinction between stimulus-driven, externally triggered actions on the one hand, and goal-driven, voluntary, self-initiated actions on the other hand (see, e.g., Gaschler & Nattkemper, 2012; Herwig et al., 2007; Janczyk et al., 2012; Pass-
ingham et al., 2010; Pfister et al., 2011, 2010). Given the implicit assumption that free-choice tasks require more or more complex decisions (what is then the reason for the longer RTs in free- compared with forced-choice tasks), such tasks are used to operationalize voluntary, self-initiated actions, while forced-choice tasks are used to operationalize externally triggered actions in contrast. The present results suggest that this implicit assumption is not necessarily true. It rather seems that response selection in forced- and free-choice tasks shows no qualitative difference. A similar conclusion has been drawn by Mattler and Palmer (2012) from a study on priming effects on free choices.

According to ideomotor approaches of action control the crucial mechanism underlying response selection is the anticipation of an action’s consequences, that is, of the effects of an action (Kunde, 2001; Paelecke & Kunde, 2007). Against this background, the present conclusion that forced- and free-choice tasks do not differ regarding response selection may be surprising because the formation and/or usage of (long-term) associations between actions and their effects was shown to be different between forced- and free-choice tasks (e.g., Herwig & Horstmann, 2011; Herwig et al., 2007; Herwig & Waszak, 2009, 2012; Pfister et al., 2011). Admittedly, these findings point to some kind of qualitative differences in response selection, but there are also studies showing an impact of action effects with pure forced-choice tasks (e.g., Janczyk et al., 2012; Janczyk, Skirde, Weigelt, & Kunde, 2009; Kühl, Elsner, Prinz, & Brass, 2009; Kunde, 2001; Pfister & Kunde, 2013; Wolfensteller & Ruge, 2011). Further, the formation of action-effect associations within one trial was shown to be equal for forced- and free-choice trials (Herwig & Waszak, 2012; Janczyk et al., 2012). The reasons for the discrepancies are unknown at present and deserve further systematic investigation (e.g., Herwig & Waszak, 2012, for an interesting explanatory mechanism). In fact, a discussion about what a self-initiated action is and how it can be experimentally operationalized has emerged recently (e.g., Frith, 2013; Nachev, Kennard, & Husain, 2008; Passingham et al., 2010; Schüür & Haggard, 2011). Our results may be taken to suggest that free-choice tasks are perhaps not the best operationalization.

Interestingly, Berlyne (1957a) has speculated about why participants show responses at all in free-choice tasks. Among other accounts, he discussed a model where all current response tendencies have spontaneous fluctuations, and any response will be emitted that exceeds the other responses’ current activation by a “certain minimum quantity $k$” (p. 115). This process takes longer in free- than in forced-choice trials, but the underlying mechanisms are the same.
Berlyne’s proposal may indeed serve as a basis for a formalization of the mechanisms underlying forced- and free-choice tasks in the contemporary framework of sequential sampling models (e.g., Hübner et al., 2010; Ratcliff, 1978). Those are able to account for response time and error distributions across a wide range of perceptual decisions. The basic idea behind sequential sampling models is that sensory evidence is accumulated over time until a pre-defined criterion is reached and a response is triggered. In this context, the present findings suggest that enhanced perceptual processing due to goal-directed if-then plans entails a high rate of sensory evidence accumulation in forced-choice tasks. Accordingly, the response criterion is rapidly reached, resulting in relatively fast response times. In comparison, free-choice tasks neither seem to facilitate perceptual processing nor do they impose a particular association between stimulus and response. Instead, stimuli presented in free-choice tasks create an ambiguous situation with essentially equivalent choice options, resulting in a low rate of evidence accumulation. Eventually, also free-choice tasks end up with a response. One conceivable option for such free-choice responses is that response criteria are lowered when no criterion is reached within a given interval or when the cognitive system detects no clear trend in evidence accumulation. Fluctuations due to noise during evidence accumulation may then exceed a criterion (randomly) and initiate a response (cf., Berlyne, 1957a; see also Mattler & Palmer, 2012). Another possibility is that evidence accumulation is not (only) based on the available perceptual input but is rather biased by other factors, such as response history.\footnote{This refers not only to the immediately preceding trial, but to the longer history of previous responses.} Assuming that such a history bias results in slower evidence accumulation than in perceptually driven forced-choice tasks, participants would respond later in a free-choice task. The finding that free-choice trials in Experiment 3 were not affected by the brightness manipulation—not even when unique stimulus forms fostered perceptual processing—does not exclude one possibility for certain. Future research may provide decisive evidence for one of these (or even other) options.

In any case, it seems plausible that performance in forced- and free-choice tasks is based on the same underlying mechanisms. That is, response criteria of forced-choice tasks are also used in free-choice tasks. This assumption is in line with the finding that both forced- and free-choice tasks do not differ in terms of susceptibility to dual-task costs (Janczyk, Nolden, & Jolicoeur, 2015). The difference between both tasks is only the time it takes to exceed an accumulation criterion at an early processing stage, which is responsible for the different response times.
Alternative Accounts

Our studies were based on the reasoning that implementation intentions (Gollwitzer, 1999) are formed in forced- but not in free-choice tasks and the results were in line with our predictions. We readily acknowledge, however, that there are possible alternative accounts which can be compatible with our findings.

One relates to the circumstance that our conclusions are mainly based on dual-task experiments. In particular, the difference between forced- and free-choice RTs always emerged at the long SOAs, where a lower level of cognitive load (compared with short SOAs) made it possible to devote more cognitive resources to decision-related processes in the free-choice task. However, albeit such an interpretation is very interesting, we see several problems. First, from the perspective of a central bottleneck model (e.g., Pashler, 1994), the decision-related processes of Task 2 can only start once the stage of Task 1 that causes the dual-task problems (i.e., its central stage) has finished. Thus, resources devoted to decision-related processes should not be affected by the SOA (and thus by high vs. low load). Second, the predictions regarding Task 2 results are essentially the same even if one does not accept bottleneck models but rather alludes to capacity sharing models like that of Tombu and Jolicoeur (2003).

Another alternative account is based on research showing that preparing for a particular motor action can enhance perception of relevant stimulus dimensions. Much of this work is embedded in the theory of event coding (TEC; Hommel, Müsseler, Aschersleben, & Prinz, 2001) and its assumption of a common representation for perceptual and action features. Preparation for an action results in weighting those perceptual dimensions more that are of particular importance for this action. For example, preparing a grasping movement facilitates detection of a size-singleton in visual search, while preparing a pointing movement facilitates detection of a luminance-singleton (Wykowska, Schubö, & Hommel, 2009). In an EEG study, Wykowska and Schubö (2012) replicated these results and additionally found effects on (early) attentional correlates such as the P1 and the N2pc component of the ERP. While these studies—in line with our conclusions—also point to perceptual sources, there is a notable difference to our results: the stimuli that distinguished the forced- from free-choice tasks in our experiments varied on a common dimension (color in Experiments 1 and 3; spatial location in Experiment 2). It might be true that perception of this particular dimension is generally facilitated by concurrent action planning, but still more facilitation was observed then for the forced- compared with the free-choice stimuli; that is, for specific values on this dimension. Evidence for stimulus-specific
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effects of action preparation comes from studies on action induced (or action effect) blindness: preparing a particular response impairs perception of stimuli sharing characteristics with the planned action (Müsseler & Hommel, 1997; Pfister, Heinemann, Kiesel, Thomaschke, & Janczyk, 2012). Forced-choice tasks could also be conceived as providing participants with explicit stimulus-response (S-R) links which—in contrast to the framework of implementation intentions—are bidirectional according to TEC (e.g., Elsner & Hommel, 2001). In other words, activation of one side spreads to activate the other side, irrespective of which part is activated first, but this spreading activation reduces the more units on one side are linked to a unit on the other side (see Metzker & Dreisbach, 2009, for evidence using a Simon task).

Consider now the situation in Experiments 1 and 3 with two responses and three stimuli. If, as Berlyne (1957b) assumed, the strength of associations of responses to their stimuli depends on their occurrence probabilities, the development of relatively strong associations between the response codes and the respective forced-choice stimulus codes can be expected. For the free-choice stimulus, however, these associations should be weaker. Critically, at the outset of a trial, all response options are activated, resulting in a state of “competing response tendencies” (Berlyne, 1957b, p. 331). Once the bidirectional S-R links have evolved and their strengths reflect Berlyne’s assumptions, response code activation should translate to higher pre-activation of the forced-choice than of the free-choice stimulus.

On the basis of the present data, it is difficult to distinguish which account is more appropriate for explaining our results. It seems likely that the TEC/bidirectional S-R link account suggests a development of the facilitation throughout the course of the experiment during which participants gain knowledge of the stimuli and their probabilities (see Berlyne, 1957b, p. 330). The implementation intention account, on the other hand, is based on the assumption that performance facilitation is due to prior planning and should thus manifest itself from the outset of the task. We tested this in exploratory analyses where we included the ordinal block number as an additional repeated measure in the analyses of Experiments 1 and 2. The critical interaction of SOA and task type was significant in all cases, but was not modified by block number (not even when the previously unanalyzed practice block was included). Thus, the advantage of forced- over free-choices was already present from the beginning of the experiments. Although this appears slightly more in line with the implementation intention framework, we find it premature to draw strong conclusions from this post hoc analysis. Instead, we summarize the two core messages of this study: first, independent of which account (implementation intentions or TEC/bidirectional S-R links) turns out as being more appropriate, both suggest facilitated perception in the
forced-choice task. Second, both approaches are not mutually incompatible. It may even be that the implementation intentions gave forced-choice stimuli a “head-start” at the beginning, and that this advantage was maintained by the developed bidirectionality of the experienced stimuli and responses over the course of the experiments. We consider this a worthwhile field for future research.

Conclusions

It is known that the formation of if-then plans or implementation intentions facilitates perceptual processing through early attentional advantages for stimuli specified in the if-part (Achtziger et al., 2012; Bieleke et al., 2015; Gollwitzer, 1999; Wieber & Sassenberg, 2006). Our results suggest that this mechanism also underlies the performance differences between forced- and free-choice tasks. Consequently, the present research also raises doubts about the suitability of these tasks to operationalize presumably different kinds of human actions. Future research should aim at providing a computational implementation that can account for the present findings and elucidate the difference between forced- and free-choice tasks in more detail.
Research Paper II

If-then Planning Enhances Selective Attention: A Diffusion Model Approach

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Abstract

We investigated whether individuals who make if-then plans (so-called implementation intentions) can strategically enhance their efficiency of information processing. Across three experiments using flanker tasks (Exp. 1, 2 and 3), we observed faster responses without a drop of accuracy to critical items specified in the if-part of an implementation intention, compared to non-specified items. To scrutinize the cognitive processes governing this improvement in performance, we fit response times and error distributions from two experiments (Exp. 1 and 3) with the dual-stage two-phase (DSTP) model, a computational sequential sampling approach that incorporates two successive phases of response selection, driven by the output of an early and a late stage of stimulus selection, respectively. Parameter estimates revealed higher drift rates for critical compared to non-critical items during early stimulus and response selection in a setup without response conflict (Exp. 1). Further, critical items yielded higher drift rates during late stimulus and response selection in a setup entailing response conflicts (Exp. 3). These findings suggest that individuals can strategically improve selective attention and hence enhance their processing efficiency of sensory information.
Introduction

Can humans exert strategic control over the efficiency of their information processing? Prior research has often neglected this question and mainly focused on how the limited capacity of the cognitive system leads to a trade-off between speed and accuracy (e.g., Fitts, 1966; Schouten & Bekker, 1967; Wickelgren, 1977; Woodworth, 1899). From this point of view, humans can choose between an emphasis on responding fast and forfeiting accuracy or responding accurately at the expense of speed, but a simultaneous optimization along both dimensions—enhancing the efficiency of information processing—is commonly not considered feasible (Heitz, 2014; Luce, 1986). One exception are attempts to instigate action control via performance-dependent financial incentives (i.e., payment depends on speed, accuracy, or both). Incentives can increase attentional effort (e.g., Kleinsorge, 2001; Sarter, Gehring, & Kozak, 2006) and this in turn results in better task performance (Hübner & Schlösser, 2010). However, such results are hardly generalizable because positive incentive effects depend on multiple factors, such as specific characteristics of the incentive scheme (Bonner & Sprinkle, 2002; Dambacher, Hübner, & Schlösser, 2011).

Thus, it is still an open question whether there are also more reliable ways to enable individuals to exert control over their processing efficiency. In the present work, we address this issue and examine effects of using a self-regulatory response strategy on perceptual decisions in several flanker tasks. We thereby combine research on if-then planning, which primarily focuses on the self-regulation of social and motivational phenomena, with research on sequential sampling modeling of performance in conflict tasks, which is concerned with basic perceptual and attentional mechanisms of information processing and cognitive control. Our findings suggest that individuals can indeed strategically enhance processing efficiency when the goal to be efficient is furnished by self-regulatory if-then plans.

The Self-regulation Strategy of If-then Planning

Making if-then plans (referred to as implementation intentions, Gollwitzer, 1993, 1999, 2014) is a self-regulation strategy that has consistently been shown to improve goal attainment and action control across a wide range of tasks (or goals). In contrast to strategies that rely on the mere specification of the desired behavior or outcome (so-called goal intentions, e.g., “I intend to show behavior B / to reach outcome O!”), implementation intentions specify a critical situation and a response that is instrumental to attain the goal intention. These two elements are then mentally linked in an if-then format:
“If I encounter situation S, then I will initiate response R!” The theory of implementation intentions predicts that attaining a goal becomes more likely when a respective if-then plan has been added. For instance, for a person with the goal of complaining about the unfriendly behavior of a colleague the following if-then plan should facilitate goal attainment: “If I meet my colleague in private, then I will tell her: Let’s be nice to each other!” Consistent with such predictions, implementation intentions have been found to help people control their behavior in order to attain their goals across a variety of domains (health, achievement, and interpersonal; for recent reviews see Adriaanse, Vinkers, et al., 2011; Bélanger-Gravel et al., 2013; Gollwitzer, 2014; Hagger & Luszczynska, 2014). A meta-analysis (Gollwitzer & Sheeran, 2006) involving more than 8,000 participants in 94 independent studies reported a medium-to-large effect size ($d = .65$) of implementation intentions on the rate of goal attainment.

To explain the positive effects of implementation intentions on action control, Gollwitzer (1993, 1999, 2014) has proposed two distinct cognitive processes. The first process relates to the identification of critical items pertaining to the specified situation, whereas the second process concerns the automatic initiation of the goal-directed response. The beneficial effects of implementation intentions are assumed to result from the combined effects of the increased item accessibility and the strong link between item and response. For instance, a person that specified the exemplary if-then plan from above is expected to easily recognize opportunities to talk privately to the colleague and use it as a cue to request being nice to each other. Further, the person is expected to readily exhibit this critical behavior as it will be initiated automatically (i.e., fast, efficiently, and without a further conscious intent). Research conducted so far supports the hypothesis that both processes together mediate the positive effects of implementation intentions on goal attainment (Gollwitzer & Oettingen, 2011).

Research on the if-part of implementation intentions commonly used two-task paradigms to test whether the accessibility of critical items is heightened. In these studies, participants in the implementation intention condition first form if-then plans containing critical items and then engage in a (allegedly unrelated) second task. This second task yields performance measures that are responsive to differences in item identification and can thus inform about relative advantages provided by implementation intentions. Aarts et al. (1999), for instance, used a lexical decision task and found that participants responded faster to words specified as critical in an implementation intention. Similar results have been reported in a word search study in which the identification of critical words was faster than the identification of neutral words (Webb & Sheeran, 2007). Due to their heightened accessibility, critical items
can be expected to have important attentional and perceptual consequences. In line with this hypothesis, Achtziger et al. (2012) reported impaired shadowing performance in a dichotic listening task when the critical item was presented to the non-attended channel. A similar failure to ignore critical items was observed by Wieber and Sassenberg (2006) who found slower target categorization when words specified in the if-part of an implementation intention were presented as distractors in a flanker task. Subsequent research by Janczyk, Dambacher, Bieleke, and Gollwitzer (2015) extended these findings by showing that critical items also benefit from facilitated earliest perceptual processing.

Research focusing on the then-part of implementation intentions has coined the term strategic automaticity (Gollwitzer, Fujita, & Oettingen, 2004; Gollwitzer & Schaal, 1998) to capture the finding that the instrumental response specified in the then-part is initiated immediately (Gollwitzer & Brandstätter, 1997; Orbell & Sheeran, 2000), efficiently (Brandstätter et al., 2001; Lengfelder & Gollwitzer, 2001), and without a further conscious intent (Bayer et al., 2009) as soon as the critical item is encountered in the environment. For example, Brandstätter et al. (2001) instructed participants to categorize visual stimuli during a cognitively straining primary task (i.e., memorizing and repeating syllables) and observed significantly faster responses to stimuli that were used as critical items in an implementation intention, compared to a goal intention condition. Similar effects were reported after subliminal presentation of critical items (Bayer et al., 2009). These results are in line with the assumption that making if-then plans forges strong mental links between the critical item and the instrumental response that allow for automatic bottom-up (i.e., stimulus-controlled) action control (Gilbert et al., 2009; Webb & Sheeran, 2007).

In summary, a considerable body of research has demonstrated that the strategy of if-then planning exerts beneficial effects on action control and goal attainment, boosting performance in a variety of tasks. So far, though, these studies have not included sequential sampling models, which offer valid tools to delineate cognitive processes by taking into account distributional data (Luce, 1986; Ratcliff, 1979). A focus on distributions yields considerable advantages over averaged data, especially in mental chronometry, because more of the available information is capitalized (Balota & Yap, 2011; Speelman & McGann, 2013; van den Wildenberg et al., 2010). In particular, sequential sampling models allow to scrutinize how experimental manipulations (e.g., response strategies) affect task performance and therefore increasingly attract attention in various domains of psychology (Voss et al., 2013). Here, we follow this approach and use a sequential sampling model to test whether
individuals can strategically enhance their processing efficiency with if-then plans.

**Sequential Sampling Models**

Sequential sampling approaches are mathematical models that, although differing in their specifics, make the same core assumption regarding information processing (e.g., Brown & Heathcote, 2008; Hübner et al., 2010; Ratcliff, 1978; Ratcliff & McKoon, 2008; P. L. Smith & Van Zandt, 2000; Usher & McClelland, 2001). Noisy information about a sensory stimulus is accumulated over time until a response threshold is reached and a respective response is initiated. Individuals have been shown to exert control over two characteristics of this process: the response thresholds and the starting point of evidence accumulation (Ratcliff, 2002; Voss, Rothermund, & Voss, 2004; Wagenmakers, Ratcliff, Gomez, & McKoon, 2008). Response thresholds can be strategically adjusted according to task instructions, incentive structures, or response deadlines that emphasize speed or accuracy. Lowering the response thresholds implies that less evidence is accumulated and results in faster but less accurate responses; in turn raising the response thresholds leads to slower but more accurate responses. Additionally, individuals can bias the starting point of information accumulation in favor of stimuli that are more likely to occur or that are rewarded.

In contrast to these two model characteristics, a third component, the efficiency of information processing that is captured as rate of evidence accumulation, is commonly considered to be outside of individual control (e.g., Voss et al., 2004; Wagenmakers, 2009). Instead, this rate is primarily regarded as being determined by task difficulty (e.g., Ratcliff, 2002; Ratcliff et al., 2004) and by stable individual capacities (e.g., working memory and intelligence; Schmiedek et al., 2007; van Ravenzwaaij et al., 2011). In order to examine whether these assumptions need to be revised, we used the dual-stage two-phase (DSTP) sequential sampling model (Hübner et al., 2010) and tested whether processing efficiency can be at least partly put under individual control when individuals have an effective response strategy (i.e., make if-then plans).

**The Dual-stage Two-phase (DSTP) Model**

The DSTP model (Hübner et al., 2010) is a sequential sampling approach that has been developed in the context of selective attention. An important advantage of the DSTP model is its ability to account for data from tasks involving response conflicts (e.g., the flanker task), a characteristic
that increasingly gains importance in the field of sequential sampling modeling (Servant, Montagnini, & Burle, 2014; van Maanen, Turner, & Forstmann, 2015). In particular, the DSTP model makes the assumption of two staggered selection processes, stimulus selection and response selection. The model focuses mainly on the dynamics of response selection, which are assumed to be strongly affected by stimulus selection.

Figure 5. An example of stimulus and response selection in the Dual-Stage Two-Phase (DSTP) model. An early stage of stimulus selection (i.e., sensory filtering/weighting) provides the drift rate \( \mu_{RS1} \) for Phase 1 of response selection. In parallel, a late stage of stimulus selection runs with rate \( \mu_{SS} \) until it reaches one of two boundaries C and –D that reflect the selection of either the target or a flanker for selective processing. On completion of the late stimulus selection SS, response selection enters Phase 2, which is characterized by a transition of the drift rate from \( \mu_{RS1} \) to \( \mu_{RS2} \). A decision is completed as soon as the response selection process (either during Phase 1 or Phase 2) hits one of two response boundaries A and –B reflecting the choice alternatives. The duration of the non-decision time (e.g., sensory encoding, sensory filtering, motor commands) is captured in parameter \( t_{er} \).

Figure 5 illustrates that response selection is divided into Phase 1 and Phase 2, represented by the diffusion processes RS1 and RS2, respectively (Ratcliff, 1978). These diffusion processes are characterized by two drift rates (parameters \( \mu_{RS1} \) and \( \mu_{RS2} \)) reflecting the evidence available for responses A
versus B. Noisy samples of evidence are accumulated over time, until one of the corresponding boundaries (parameters A and -B) is reached and the associated response is triggered. Similar to other sequential sampling models, higher drift rates are indicative of faster evidence accumulation and hence reflect enhanced processing efficiency.

In Phase 1 of response selection, the efficiency of information processing (i.e., $\mu_{RS1}$) is determined by an early stage of stimulus selection, representing a sensory filter that enhances or attenuates the impact of stimulus components. In the domain of visual perception, for example, this filter is often described as a spotlight that can be allocated to a certain location in space. Items at that location are then processed more intensively than items at other positions (Posner, 1980; Posner et al., 1980). For instance, in the flanker tasks used in the present study the central stimulus component is always the target and therefore receives higher attentional weights than non-central flanker components. The product of sensory bottom-up processes and the attentional weights provides the drift rates indexing the processing efficiency of the response-relevant target (parameter $\mu_{ta}$) and the irrelevant flanker (parameter $\mu_{fl}$). Both rates sum up to the total drift rate $\mu_{RS1}$ for Phase 1 of response selection (i.e., $\mu_{RS1} = \mu_{ta} + \mu_{fl}$). In classical flanker tasks, the value of $\mu_{fl}$ is positive if the flankers are response-compatible (i.e., congruent stimuli) and it is negative if they are response-incompatible (i.e., incongruent stimuli). Thus, the overall drift rate for Phase 1 of response selection is reduced for incongruent compared to congruent stimuli, and can even be negative.

If response selection relied only on this early phase there would be no qualitative improvement over time, and accuracy for incongruent stimuli would remain at a relatively low level. Empirical data show, however, that such a simple mechanism is insufficient to account for response distributions in flanker tasks. Therefore, Hübner et al. (2010) proposed that a more sophisticated late stage of stimulus selection runs in parallel with Phase 1 of response selection. The late stage has the function to select only response-relevant items for processing and is implemented as an independent diffusion process $SS$. When stimulus selection (parameter $\mu_{SS}$) hits one of its boundaries (parameters C and -D), either the target or a flanker item of a stimulus is selected for further processing, whereas unselected stimulus components are henceforth ignored. Thus, once the late stimulus selection process is finished, and given that no response has been selected yet, response selection enters Phase 2, in which only the selected item drives response selection at a new drift rate for late response selection (parameter $\mu_{RS2}$). As a consequence, the rate of response selection changes from Phase 1 to Phase 2 according to two possible scenarios: First, when late stimulus selection correctly selected
the target, the drift rate in Phase 2 of response selection is usually higher than in Phase 1 (i.e., $\mu_{RS2} > \mu_{RS1}$), especially for incongruent stimuli. Second, when late stimulus selection erroneously selects the flanker, the drift rate in Phase 2 of response selection depends on the response-compatibility of the flanker. If it is incongruent, the drift rate is negative (i.e., $\mu_{RS2} < 0$) and leads with high probability to an error. If the flanker is congruent, the drift rate is positive (i.e., $\mu_{RS2} > 0$). Response selection usually enters Phase 2 in a substantial proportion of trials, which explains why accuracy is higher for slow than for fast responses.

Finally, while Phases 1 and 2 of response selection reflect the duration of the central decision process, the DSTP model also captures non-decisional phases (parameter $t_{er}$), which comprise the duration of pre-decisional processes, such as stimulus encoding or sensory filtering (i.e., the early stage of stimulus selection), as well as of post-decisional processes, such as motor planning or response execution.

**Possible Effects of If-then Planning on DSTP Model Parameters**

The cognitive processes mediating potential effects of response strategies on task performance can be assumed to manifest themselves in the parameters of the DSTP model. More specifically, in the present case of if-then plans, the suggested enhancement of item accessibility and automaticity of response initiation imply an advantage for the specified critical item and the respective response. However, several hypotheses are conceivable regarding the exact underlying mechanisms.

First, making if-then plans could improve the focus on specific characteristics of the critical item (i.e., selective attention) over time. Accordingly, beneficial effects on task performance could arise from an enhanced efficiency of the early and/or late stages of selective attention (Hübner et al., 2010), represented by the drift rates $\mu_{RS1}$ and $\mu_{SS}$ in the DSTP model, respectively. Second, the stronger item-response association afforded by if-then planning could increase the efficiency of the critical as compared to alternative responses, so that the correct response is initiated faster. Such a cognitive advantage for response selection is represented by the drift rate $\mu_{RS2}$. Third, in contrast to an increase of processing efficiency, it is also conceivable that making if-then plans provides a largely motoric advantage and thus speeds up the execution of the critical response, represented by the non-decisional component $t_{er}$. For instance, if-then plans could enhance the speed of motor commands via a constant pre-activation of response-relevant motor programs.
Finally, one might also argue that if-then plans do not affect processing efficiency, but lead to a strategic modulation of response thresholds or biases. This, however, implies that shorter response latencies are necessarily accompanied by an increase in error rates, a pattern that is at odds with prior research on implementation intentions, which has repeatedly demonstrated that gains in response times are achieved without forfeiting accuracy (e.g., Brandstätter et al., 2001).

**The Present Research**

The aim of the present research was to test whether a response strategy, such as making if-then plans, enables individuals to enhance the efficiency of information processing. Across three experiments, we used different variations of the flanker task (B. A. Eriksen & Eriksen, 1974) and encouraged participants to furnish their goals to work efficiently with if-then plans (i.e., implementation intentions). In Experiment 1 we tested whether and how making if-then plans enhances processing efficiency when response selection is largely based on relatively simple sensory information rather than on more complex mechanisms of attentional selectivity. This was realized in a simplified flanker task with response-neutral flankers and a one-to-one mapping of responses to stimuli. Response time and error data were then fit with the DSTP model (Hübner et al., 2010) to establish the processes driving the effects of if-then plans. By adding response-incongruent flankers to the task in Experiment 2, we then tested whether if-then plans can also enhance information processing efficiency in a setup entailing response conflict, that is, when response selection requires attentional selectivity. Finally, in Experiment 3 we employed a setup involving response conflicts and a sizeable stimulus set size. This allowed us to fully scrutinize the cognitive processes underlying the effects on processing efficiency and attentional selectivity by again fitting response time and error data with the DSTP model.

**Experiment 1**

In Experiment 1, we examined whether individuals can strategically enhance processing efficiency when response selection is driven by stimuli that induce no response conflict. For this objective we used a simplified flanker task in which two targets were mapped one-to-one to two responses. The flankers were not associated with any of these responses (i.e., response-neutral flankers), but their features overlapped to some extent with those of both tar-
gets and therefore required sensory filtering to discern between the central target and the irrelevant flankers.

We randomly assigned participants to a (1) familiarization, (2) goal intention, or (3) an implementation intention condition. In these conditions, one target (critical item) was accentuated relative to the other one (non-critical item) by means of (1) familiarization, (2) a combination of familiarization and goal intention, or (3) a combination of familiarization and goal intention plus if-then plan, respectively. Although our primary goal was to investigate whether the strategy of making if-then plans enables individuals to enhance processing efficiency, we included the additional control conditions of familiarization and goal intention in our first experiment to rule out apparent alternative sources of enhanced processing efficiency. In particular, participants might prioritize the critical item highlighted in the if-then plan over the remaining non-critical items and allocate their attentional resources accordingly. We therefore highlighted the critical item in all three conditions and asked participants to familiarize themselves with this item. Further, participants making if-then plans might have a higher motivation to work fast and accurately. We therefore encouraged participants in the goal intention condition to commit themselves to an efficiency goal as well. On the basis of prior research on implementation intentions, however, we expected that only the formation of if-then plans leads to enhanced processing efficiency of the critical item and hence to faster and/or more accurate responses to the critical item compared to the non-critical item.

Given the perceptual nature of this experiment, we assumed that fits of the DSTP model reveal enhanced sensory filtering in the early stage of stimulus selection, tantamount to a higher drift rate $\mu_{RS1}$ for the critical item compared to the non-critical item. Yet, we also considered the possibility that the effect shows up in other DSTP drift rates (i.e., $\mu_{RS2}$ and $\mu_{SS}$) and/or in the non-decisional time component (i.e., $t_{er}$) as well. However, as prior research on implementation intentions has shown that making if-then plans speeds up responses without increasing error rates, we expected no speed-accuracy tradeoff for the critical item.

**Method**

**Participants**

Ninety University of Konstanz students (61 females) with a mean age of 23.6 years ($SD = 4.8$) were recruited using the online recruitment system ORSEE (Greiner, 2015). They were compensated with €6 for participating in the 45 min experiment.
Materials

The experiment was presented on an LCD monitor with a resolution of 1280 × 1024 pixels and at a 60 Hertz refresh rate. Stimuli were displayed in white on a black background. Four digits (0, 2, 5, and 8) in a digital font were used in the flanker task (see top panel in Table 1). The digits 2 and 5 were used as targets because they have identical perceptual features in the digital font (i.e., they are mirror images of each other). As a consequence, feature differences cannot account for possible performance differences between the targets. The digits 0 and 8 were used as flankers because each is equally similar to both targets. However, the 8 shares more perceptual features with both targets than the 0 and is thus more difficult to distinguish from them (Duncan & Humphreys, 1989). This allowed a comparison of performance in easy versus difficult trials. Taken together, using the four digits resulted in a set of four stimuli (e.g., 00200; see Table 3). All stimuli were presented equally often and the order of presentation was randomized at the individual level.

Design

The experiment adopted a 3 between (Condition: familiarization vs. goal intention vs. implementation intention) × 2 within (Item: critical vs. non-critical) × 2 within (Flanker: easy vs. difficult) mixed factorial design.

Procedure

Participants were invited to a study investigating fast and accurate decision making. They received general task instructions and practice trials, followed by a task preparation according to their experimental condition. A final questionnaire assessing goal commitment and demographics concluded the experiment.

Instructions and practice trials. The general instructions described the flanker task and asked participants to categorize the target digits as fast and accurately as possible, while ignoring the flanker digits. This was followed by 8 practice trials to familiarize participants with the task.

Task preparation. Participants in all three conditions were first asked to make themselves familiar with one of the targets (i.e., either the 2 or the 5, counterbalanced across participants) by drawing it once on a sheet of paper. This item is referred to as the critical item in all three conditions, in contrast
Table 3. Stimulus sets used in experiments 1 to 3.

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Congruency</th>
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<tr>
<td></td>
<td>congruent</td>
<td>neutral</td>
<td>incongruent</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td></td>
<td></td>
<td>00200 00500</td>
<td>88288 88588</td>
<td></td>
</tr>
<tr>
<td></td>
<td>SSSSS</td>
<td>HHHHH</td>
<td>BBSBB</td>
<td>BBHBB</td>
<td></td>
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<tr>
<td></td>
<td>HSHSS</td>
<td>SSHSS</td>
<td>KSKKK</td>
<td>KKHKK</td>
<td></td>
</tr>
<tr>
<td></td>
<td>BBBBB</td>
<td>KKKKK</td>
<td>SSBSS</td>
<td>SSKSS</td>
<td></td>
</tr>
<tr>
<td></td>
<td>KKBKK</td>
<td>BBKBB</td>
<td>HHBHH</td>
<td>HHKHH</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
<td>24</td>
<td>35</td>
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<td>3</td>
<td></td>
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<td>24</td>
<td>35</td>
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</table>

Experiment 1
to the non-critical item with which participants did not familiarize themselves. Participants in the goal intention and the implementation intention condition were additionally instructed to adopt the following efficiency goal (i.e., goal intention): “I will work as fast and as accurately as possible!” On top of that, participants in the implementation intention condition were encouraged to furnish this efficiency goal by making the following if-then plan for the critical item: “And if I see the number 2 [5], then I will immediately press the left [right] mouse button!”

**Flanker task.** After the task preparation, participants worked on 8 blocks of 64 flanker task trials (512 trials in total). Each trial started with a fixation cross presented for 500 ms at one of nine possible positions in an imaginary rectangle (i.e., at 40, 50, or 60% of the horizontal and vertical screen axis, respectively). The screen then turned black for 600 ms upon which the flanked target was presented for 165 ms centered at the position of the preceding fixation cross. Another blank screen followed and disappeared after 1835 ms unless the participant responded prior to this by pressing either the left or the right computer mouse button. Response time feedback was provided by presenting the prompt “PLEASE RESPOND FASTER!” whenever participants responded later than 900 ms after stimulus onset. The prompt appeared in the middle of the screen for 1000 ms. No accuracy feedback was provided. The sequence of events during a single trial is depicted in Figure 6.

**Final questionnaire.** In the final questionnaire, we first measured commitment to the efficiency goal assigned in the goal intention and the implementation intention conditions using a set of five items (e.g., “I was strongly committed to pursuing this goal.”, “It was hard to take this goal seriously.”, “It wouldn’t have taken much to make me abandon this goal.”) that has been validated for research purposes (Hollenbeck, Klein, O’Leary, & Wright, 1989; Klein, Wesson, Hollenbeck, Wright, & DeShon, 2001). Commitment to the assigned if-then plan was measured with a similar set of five items (e.g., “I was determined to implement the plan.”, “I didn’t care whether I could realize the plan.”, “I never doubted that this plan is important.”). All items were assessed on 7-point Likert scales ranging from 1 (does not apply) to 7 (does fully apply). Finally, participants answered standard demographic questions (e.g., age and gender).
Results

Goal and plan commitment

The items for measuring goal commitment ($\alpha = 0.74$) and plan commitment ($\alpha = 0.78$) exhibited a similarly high reliability that is in line with commitment measures reported in the literature (Klein et al., 2001). We thus collapsed the respective items using the mean scores of each scale as commitment measures. Goal commitment was comparably high in the goal intention ($M = 5.2$, $SD = 1.3$) and the implementation intention ($M = 5.4$, $SD = 0.9$) conditions, $t(58) = 0.631$, $p = .530$, $d = 0.16$. Participants in the implementation intention condition were also highly committed to their plan, $M = 5.8$ on a 7-point scale, $SD = 1.0$.

Data pre-treatment and analysis

Responses faster than 100 ms or slower than 1200 ms were excluded from data analysis (0.12% of all data). Error trials were removed for the response time analyses. Mean response times and error rates were subjected to an analysis of variance (ANOVA) with Condition (familiarization vs. goal intention vs. implementation intention) as between-subject factor and Item (critical
vs. non-critical) and Flanker (easy vs. difficult) as within-subject factors. The data were analyzed using the software R, version 3.1.1 (R Core Team, 2014), and they were visualized using the ggplot2 package implemented in the R framework (Wickham, 2009).

Response times

The analysis of response times (Figure 7 (a)) revealed a significant main effect of Flanker, $F(1,87) = 193.75, p < .001, \eta^2_p = .690$. Responses were faster for the easy than for the difficult flanker (431 versus 443 ms). Furthermore, a significant interaction effect of Condition and Item evinced, $F(2,87) = 3.14, p = .048, \eta^2_p = .067$. Planned post-hoc tests yielded faster responses to the critical than to the non-critical item in the implementation intention condition only, $F(1,29) = 5.60, p = .025, \eta^2_p = .162$ (implementation intention: 425 versus 435 ms; familiarization: 439 versus 437 ms; goal intention: 445 versus 440 ms). All other main effects and interactions were not significant ($ps > .30$).

Error rates

The error rate analysis (Figure 7 (b)) revealed a significant main effect of Flanker, $F(1,87) = 16.67, p < .001, \eta^2_p = .161$. Fewer errors were made in trials with the easy compared to the difficult flanker (5.5 versus 6.5%). All
other main effects and interactions were not significant ($p_s > .19$). Importantly, in the implementation intention condition the error rate was numerically lower for critical than for non-critical items (5.9 versus 7.0%). This indicates that the faster response times to critical than non-critical items in the implementation intention condition did not produce a speed-accuracy tradeoff.

**DSTP analysis**

Participants in the implementation intention condition showed better performance for critical than for non-critical items, irrespective of whether the flanker was easy or difficult. In contrast, the familiarization and the goal intention condition yielded no advantage for critical items. We therefore refrained from fitting the DSTP model to data from these control conditions and focused on our hypothesis that improved performance under strategic if-then planning results from enhanced efficiency of information processing. We therefore collapsed the data across the easy and the difficult flankers and fit the DSTP model to the response distributions of critical and non-critical items in the implementation intention condition.

**Cumulative distribution and conditional accuracy functions.** Cumulative distribution functions (CDFs) for correct responses were computed from quantile-based (.1, .3, .5, .7, and .9) averages of response times for critical and non-critical items in the implementation intention condition. Thus, correct responses were sorted into six response time bins comprising 10%, 20%, 20%, 20%, 20%, and 10% of the data, respectively (Ratcliff, 1979).

The error rates were considered by means of conditional accuracy functions (CAFs), which specify how accuracy varies with response time. CAFs can be calculated even for conditions in which some participants make few or no errors. We were therefore able to take into account data from all participants for the model fit analyses, whereas common error CDFs would have required the exclusion of data sets with too few errors. We calculated CAFs as mean response time and proportion of correct responses in each of five 20%-quantiles of the response time distribution from each participant, separately for critical and non-critical items.

**Model fitting procedure.** As in previous research, a computer-simulation version of the DSTP model was fit to the distributional data (e.g., Hübner et al., 2010). Specifically, the PRAXIS algorithm (Brent, 1973; Gegenfurtner, 1992) was applied to find parameter values minimizing the $G^2$ statistic (Wilk’s likelihood ratio chi-square; Ratcliff et al., 2004):
$G^2 = 2 \sum_{i=1}^{J} N p_i \ln \left( \frac{p_i}{\pi_i} \right)$

where $N$ is the number of observations, $J$ is the number of bins, $p_i$ is the proportion of observations in the $i$th bin, and $\pi_i$ is the proportion in this bin predicted by the model. For $N$, we used the average number of valid trials per person in the corresponding fit condition. This was uncritical, because $G^2$ was inappropriate for significance testing and merely served as goodness-of-fit measure (Ratcliff et al., 2004). Starting from different sets of parameter values to avoid local minima, each fit was continued until $G^2$ was minimized. For each of the required several hundred cycles, $8 \times 10^5$ trials were simulated.

We fit the DSTP model to the proportions of correct responses in the CDF bins, and to the error proportions in the CAF bins (Dambacher & Hübner, 2015). Because data for critical and non-critical targets were fit simultaneously, we had $J = 22$ bins for each fit (6 bins for correct responses to critical items, 5 bins for incorrect responses to critical items, 6 bins for correct responses to non-critical items, and 5 bins for incorrect responses to non-critical items). The degrees of freedom ($df$) of the goodness-of-fit statistics were computed as

$$df = (J_c - 1) + (J_{nc} - 1) - M$$

with $J_c$ and $J_{nc}$ reflecting the number of bins for the critical and non-critical item, respectively, and $M$ representing the number of model parameters.

The following assumptions were made to restrict the number of parameters of the model in Experiment 1. First, we assumed symmetric boundaries for both response ($A = B$) and stimulus selection ($C = D$). Second, the starting point of evidence accumulation $X_0$ was zero in each trial. Third, because all flankers in Experiment 1 were response-neutral and because the empirical data were collapsed across easy and difficult flankers, the drift rate in Phase 1 of response selection was estimated as a single parameter $\mu_{RS1}$ instead of two separate parameters for target ($\mu_{ta}$) and flanker processing ($\mu_B$). Fourth, because only the target, but not the flanker components of a stimulus was linked to a response, the late stage of stimulus selection always selected the target item. Thus, the process SS determines the duration of late stimulus selection, but the rate of the subsequent Phase 2 of response selection ($\mu_{RS2}$) had always the same magnitude.

The model reported below (M1, see Table 4) allowed two parameters $\mu_{RS1}$ and $t_{er}$ to vary between critical and non-critical items, whereas one
common value for critical and non-critical items was estimated for each of the other parameters. This specification has several reasons: First, simultaneous estimates of all DSTP parameters for both critical and non-critical items were impractical because the fit procedure would not always converge due to too many free parameters (i.e., 12 instead of 8 parameters). Second, parameters $\mu_{RS1}$ and $t_{er}$ are plausible sources of implementation intention effects. This conclusion was derived from a number of alternative models, in which we varied one parameter (i.e., $\mu_{RS1}$, $\mu_{SS}$, $\mu_{RS2}$, or $t_{er}$) at a time across item conditions (see M2 to M5, reported in Table 2). Specifically, these models revealed reasonable fits for variations of parameter $\mu_{RS1}$ (M2) and $t_{er}$ (M3), whereas parameters $\mu_{SS}$ (M4) or $\mu_{RS2}$ (M5) yielded considerable worse $G^2$ goodness of fit measures. Third, as argued before, we did not explicitly consider critical item effects on thresholds for response selection (A and B) or stimulus selection (C and D), because the randomized presentation of trials with critical and non-critical items as well as the absence of a speed-accuracy tradeoff in the empirical data made distinct threshold adjustments for critical and non-critical items implausible.

These issues narrowed down the number of possible sources for implementation intention effects in Experiment 1, but they left open whether improved performance was associated with the drift rate $\mu_{RS1}$ or the non-decisional component $t_{er}$. We therefore fit the data with an 8-parameters version of the DSTP model (M1, Table 4): two response selection drift rates $\mu_{RS1}$ for each, the critical and the non-critical item; two non-decisional components $t_{er}$ for each, the critical and the non-critical item; a threshold parameter A = B for response selection; rate $\mu_{RS2}$ for response selection in Phase 2; rate $\mu_{SS}$ for late stimulus selection; a threshold parameter C = D for late stimulus selection. Accordingly, this model comprised $df = (11−1)+(11−1)−8 = 12$.

Parameters were estimated with a jackknife procedure (Gray & Schucany, 1972; Jackson, 1986; Mosteller & Tukey, 1977), where a set of parameter values $P_i$ is computed for each subject $i$ ($i = 1,\ldots,n$) by temporarily omitting participant $i$ and fitting the model to the averaged data from the remaining $n−1$ participants. The resulting parameter sets (i.e., one for each subject) can then be used for statistical analyses, such as ANOVAs. We were therefore able to test whether the variation of the two critical parameters $\mu_{RS1}$ and $t_{er}$ across target conditions was statistically significant. As the reduction of error variance due to the jackknifing leads to artificially large F-values, corrected values were computed as (Ulrich & Miller, 2001):

$$F_{cor} = \frac{F}{(n−1)}$$
Table 4. Parameter estimates obtained by fitting the DSTP model to CDFs (correct responses) and CAFs (error rates) for critical and non-critical items in the implementation intention condition in Experiment 1.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Early selection</th>
<th>Late selection</th>
<th>Fit</th>
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<tbody>
<tr>
<td>Model</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>M1</td>
<td>CI 0.151</td>
<td>0.056</td>
<td>0.331</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>M2</td>
<td>CI 0.156</td>
<td>0.058</td>
<td>0.337</td>
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<td></td>
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<tr>
<td>M3</td>
<td>CI 0.154</td>
<td>0.056</td>
<td>0.333</td>
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<tr>
<td>M4</td>
<td>CI 0.152</td>
<td>0.056</td>
<td>0.352</td>
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<tr>
<td>M5</td>
<td>CI 0.153</td>
<td>0.056</td>
<td>0.333</td>
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</table>

Note: The estimates for M1 represent the mean values obtained by the Jackknife procedure. CI = critical item; NI = non-critical item; RS1 = drift rate for Phase 1; A/B = response selection boundaries; SS = drift rate for stimulus selection; C/D = stimulus selection boundaries; RS2 = drift rates in Phase 2; t = non-decision time (in seconds); G = stimulus selection time (in seconds).
Fitting results. Average parameters for the DSTP fit to the data of Experiment 1 are listed in Table 4 (M1). The corresponding CDFs and CAFs are plotted in Figure 8. Separate ANOVAs for the stimulus-dependent parameters revealed that the drift rate in Phase 1 of response selection $\mu_{RS1}$ was enhanced for critical compared to non-critical items, $F_{cor}(1, 29) = 5.79, p < .05$. In contrast, differences of the non-decisional component $t_a$ were not reliable between items. Notably, compared to the other models M2 to M5 in Table 4, M1 provided the best fit to the data in terms of the $G^2$ statistic. Yet, its additional parameters led to a higher BIC, suggesting that one of the two variable parameters should be dropped. Because $\mu_{RS1}$ but not $t_a$ reliably accounted for variance between critical and non-critical items, the analysis indicates that the preferable model in terms of parsimony and goodness of fit is M2, in which critical and non-critical item effects are captured by two separate parameters $\mu_{RS1}$, whereas both item conditions share one value in all other parameters. Thus, the model fits are compatible with the idea that the positive effect of if-then plans is based on the enhanced efficiency of sensory filtering, resulting in a higher drift rate of early response selection rather than a speed-up of motor commands.

![Figure 8](image_url)

**Figure 8.** Cumulative probability functions (a; CDFs) and conditional accuracy functions (b; CAFs) for data in the implementation intention condition in Experiment 1. Lines represent estimates from Model M1 and data points represent observed data.
Discussion

The behavioral results of Experiment 1 show that individuals making if-then plans can improve performance for a particular stimulus in a task in which responses are strongly driven by sensory information. Participants in the implementation intention condition categorized critical item faster than non-critical items at the same level of accuracy. Importantly, such an effect was not observed in the familiarization and goal intention conditions, demonstrating that performance did not benefit from merely drawing participants’ attention to a specific stimulus, nor from increasing their motivation to work efficiently. Taken together, the behavioral results are compatible with our prediction that individuals who make if-then plans can enhance the efficiency of their information processing.

The DSTP analysis further corroborated this conclusion. Specifically, if-then plans facilitated early stimulus selection, resulting in an improved drift rate for critical compared to non-critical items during Phase 1 of response selection ($\mu_{RS1}$). No effects on the efficiency of late stimulus selection or Phase 2 of response selection ($\mu_{SS}$ and $\mu_{RS2}$, respectively) were observed, and the influence of implementation intentions on the non-decisional time ($t_{er}$) was not significant. Thus, the DSTP model suggests that making if-then plans facilitated performance primarily by improving early sensory filtering and weighting of perceptual information, which in turn gave rise to a more efficient selection of the correct response.

In summary, these findings are well in line with our expectations. However, a shortcoming of Experiment 1 is its limited generalizability due to the use of a simplified flanker task. While this simplicity allowed us to make straightforward predictions concerning the perceptual effects of if-then plans, it might bias our interpretation in important ways. First, implementation intentions are known to work particularly well in difficult task setups (e.g., Gollwitzer & Brandstätter, 1997; Wieber, Odenthal, & Gollwitzer, 2010), and the simple task of Experiment 1 might thus underestimate individuals’ ability to strategically enhance selective attention. Second and relatedly, the lack of response-incongruent flankers and the one-to-one mapping of stimuli and responses emphasized sensory information but did not require more complex processes such as late attentional selectivity. This might explain why the DSTP fits did not show effects on late stimulus selection or Phase 2 of response selection. The following experiments addressed these issues by turning to more standard flanker task setups.
Experiment 2

To rule out the possibility that the effects in Experiment 1 only emerged due to the absence of response conflicts, we replicated the results in the implementation intention condition in a very similar pilot study, which included response-congruent and response-incongruent flankers in addition to neutral stimuli. In this pilot study, participants with an if-then plan ($N = 36$) responded faster to critical as compared to non-critical items in congruent, neutral, and incongruent trials—again without a drop in accuracy. These results encouraged us to change the procedural details in Experiment 2 on several dimensions to enhance the generalizability of our findings to standard flanker tasks. First, we used trials with response-congruent and response-incongruent flankers in addition to trials with response-neutral flankers. Whereas congruent flanker trials are commonly characterized by fast responses and low error rates due to the co-activation of the correct response, incongruent flankers co-activate the wrong response and hence result in slower responses and higher error rates. Incongruent flankers thus introduce a response conflict (C. W. Eriksen & James, 1986; Gratton, Coles, & Donchin, 1992; Hübner et al., 2010) that renders the task more difficult and strengthens the importance of attentional selectivity, which permits response selection based on relevant information while minimizing flanker influences. Second, we replaced the rather small and atypical set of digital-font numerals by a larger set of letters in Arial font. Third, we added error feedback to the response time feedback to equally stress the importance of both response speed and accuracy.

The stimulus set in Experiment 2 provides further ways of testing the perceptual and attentional efficiency under strategic if-then planning. Whereas the critical items in Experiment 1 were confined to the response-relevant target position, the critical items in Experiment 2 also appeared at the flanker positions. As mentioned above, making if-then plans instigates bottom-up (i.e., stimulus-controlled) action control (Gilbert et al., 2009), implying that the critical item receives prioritized early perceptual processing (Janczyk, Dambacher, et al., 2015) and automatically taps attentional resources (Achtziger et al., 2012; Wieber & Sassenberg, 2006). Accordingly, if-then plans in Experiment 2 should affect processing efficiency not only when the critical item appears at the target but also at the flanker position. More specifically, we predict an amplification of the congruency effect: When the critical item appears at the flanker position, the correct (in congruent trials) or incorrect (in incongruent trials) response should be co-activated more strongly than when the flanker is a non-critical item. Such a critical flanker
should accordingly enhance performance in congruent trials and impair it in incongruent trials.

**Method**

**Participants**

Forty-one students of the University Konstanz were recruited using ORSEE (Greiner, 2015). One participant reported to have made if-then plans for all items and was excluded from the analysis. Two participants specified an item in the if-part of their implementation intention that was different from the requested one (e.g., “S” instead of “B”); we therefore recoded this item as critical. Seven participants specified two items in the if-part of their implementation intention, the one requested in the instructions and additionally the one associated with the same response (e.g., “If I see an S or H in the middle of the screen, then I will immediately press the left mouse button!”); their data were included in the analyses.\(^7\) The effective sample size accordingly was 40 (30 female) participants with a mean age of 22.6 years (\(SD = 4.6\)). Participants were compensated with €8 for participating in the 60 min experiment.

**Materials**

All participants were assigned to an if-then plan; the critical item identity was counter-balanced across participants. The Arial font letters S, H, B, and K served both as targets and flankers, resulting in a set of 16 stimuli (8 congruent and 8 incongruent, see Table 3). All stimuli were presented equally often and the order of presentation was randomized at the individual level. It should be noted, though, that Experiment 2 used an imbalanced design because some factor level combinations are logically impossible. If, for instance, the critical item appeared in both the target and the flanker position, the trial is necessarily congruent because target and flanker are identical.

\(^7\)Note that including these seven participants provides a particularly rigorous test of our hypothesis. It is conceivable that specifying an additional item in the if-part of the implementation intention yields similar beneficial effects on processing efficiency as for the instructed item. Yet, because the additional item is treated as non-critical in the analyses below we obtain a more conservative estimate of the if-then plan effect.
Procedure

The procedural details deviated only in minor aspects from those described for the implementation intention condition in Experiment 1. First, we used a larger number of practice trials (i.e., 32) and participants ran through 8 blocks of 96 task trials (768 altogether). Second, the fixation cross and the stimuli were always presented in the center of the screen. Third, we adjusted the if-then plan to the fact that the critical item could now appear in the flanker position (e.g., “And if I see an S in the middle, then I will immediately press the left mouse button!”) to avoid task confusion among participants. Fourth, participants did not draw the critical item prior to making the if-then plan, that is, there was no explicit familiarization with the critical item. Fifth, we provided accuracy feedback (“WRONG BUTTON!”) in addition to a response time feedback for responses given later than 900 ms after stimulus onset (“TOO SLOW!”). In cases of wrong responses given later than 900 ms after stimulus onset both prompts were displayed simultaneously on the screen.

Results

Goal and plan commitment

The reliability of the goal commitment ($\alpha = 0.63$) and the plan commitment ($\alpha = 0.76$) were appropriate. Participants were again highly committed to both the goal intention ($M = 5.1$, $SD = 1.0$) and the implementation intention ($M = 5.1$, $SD = 1.1$).

Data pre-treatment and analysis

Responses faster than 100 ms or slower than 1200 ms were excluded from data analysis (0.28% of all data). Error trials were removed for the response time analyses. For both response times and errors we conducted two types of analyses: First, target effect analyses examined effects between critical vs. non-critical items at the target position (Figures 9 (a-b)). Second, flanker effect analyses examined differences between critical vs. non-critical items at the flanker positions (Figures 9 (c-d)). The corresponding data were subjected to ANOVAs with Congruency (congruent vs. incongruent) and Item (critical vs. non-critical) as within-subject factors.
Response times: Target effects

The target effect analysis of response times revealed significant main effects of Congruency, $F(1, 39) = 181.79, p < .001, \eta^2_p = .823$, and Item, $F(1, 39) = 4.81, p = .034, \eta^2_p = .110$. Responses were slower in incongruent (501 ms) compared to congruent (473 ms) trials (Figure 9 (a)). Furthermore, participants responded faster to critical than to non-critical items (481 versus...
The interaction effect of Congruency and Item was not significant, $F < 1$.

**Response times: Flanker effects**

The flanker effect analysis of response times revealed that responses in congruent trials were faster for critical (467 ms) than for non-critical items (479 ms), $F(1, 39) = 10.94, p = .002, \eta_p^2 = .219$, whereas responses in incongruent trials tended to be slower for critical (509 ms) than for non-critical items (501 ms), $F(1, 39) = 3.64, p = .064, \eta_p^2 = .085$, resulting in a significant interaction effect of Congruency and Item, $F(1, 39) = 7.63, p = .009, \eta_p^2 = .045$ (see also Figure 9 (c)). Furthermore, the congruency effect was significant in both critical, $F(1, 39) = 62.40, p < .001, \eta_p^2 = .615$, and non-critical trials, $F(1, 39) = 66.44, p < .001, \eta_p^2 = .63$, yielding an overall significant main effect of Congruency, $F(1, 39) = 179.01, p < .001, \eta_p^2 = .821$. The main effect of Item was not significant, $F < 1$.

**Error rates: Target effects**

The target effect analysis of error rates revealed a significant main effect of Congruency, $F(1, 39) = 25.68, p < .001, \eta_p^2 = .397$. More errors were made in incongruent (10.4%) compared to congruent (7.1%) trials (Figure 9 (b)). Notably, the main effect of Item approached significance, $F(1, 39) = 2.84, p = .10, \eta_p^2 = .068$, because participants tended to make less errors in trials with critical (7.9%) than non-critical (9.6%) items. Furthermore, the interaction effect of Item and Congruency approached significance, $F(1, 39) = 3.49, p = .069, \eta_p^2 = .082$. Although error rates were always lower for critical compared to non-critical items, this difference was smaller for congruent (critical: 6.7%; non-critical: 7.5%) than for incongruent (critical: 9.1%; non-critical: 11.7%) trials.

**Error rates: Flanker effects**

The flanker effect analysis of error rates revealed a significant main effect of Congruency, $F(1, 39) = 32.34, p < .001, \eta_p^2 = .453$, as well as a significant main effect of Item, $F(1, 39) = 5.21, p = .028, \eta_p^2 = .118$. More errors were made in trials with critical (9.8%) compared to non-critical (8.9%) items (Figure 9 (d)). The interaction effect of Congruency and Item was not significant ($p = .179$).
Discussion

The results from Experiment 2 corroborate our hypothesis that if-then plans enable individuals to enhance the processing efficiency of critical compared to non-critical items. The effect was found for congruent as well as for incongruent trials in a large stimulus set with one-to-many mappings of responses to items. In addition, Experiment 2 revealed a strong modulation of the congruency effect when the critical item appeared at the flanker position. Such a critical flanker enhanced performance in congruent trials but impaired it in incongruent trials. In accordance with prior research on implementation intentions (Achtziger et al., 2012; Janczyk, Dambacher, et al., 2015; Wieber & Sassenberg, 2006), the critical item specified in the if-then plan received perceptual and attentional priority independent of task requirements. Taken together, the results from Experiment 2 replicate those obtained in Experiment 1 in a response-conflict setup of the flanker task and thus provide additional evidence for the bottom-up automatic action control afforded by implementation intentions.

While Experiment 2 allowed us to generalize the findings from Experiment 1 to tasks with a stronger emphasis on response selection and to conditions with the critical item at target and at flanker positions, the latter condition also confounded the experimental factors. For instance, when the critical item appeared in both the target and the flanker position, the trial was necessarily congruent because target and flanker were identical. This prohibits an unambiguous assessment of how if-then plans affect selective attention under response conflicts, especially because the design of Experiment 2 does not permit a straightforward fit of the DSTP model to the data. We overcame this limitation with a modified flanker task in Experiment 3.

Experiment 3

In Experiment 3, we used a flanker task that again comprised a sizeable stimulus set with congruent and incongruent flankers. In contrast to Experiment 2, however, the critical item specified in the if-then plan appeared at the target but never at the flanker positions, similar to Experiment 1. This was achieved by using digits (i.e., 2, 3, 4, and 5) as targets only (among them one critical item), whereas arrows (i.e., < and >) were used as both targets and flankers (but never as critical items). As a consequence, we were able to isolate the postulated effects on critical target items in a flanker task with response conflict and to fit the DSTP model to the data. This allowed us
to fully scrutinize the effects of strategic if-then planning on the efficiency of sensory processing and attentional selectivity.

As in the previous experiments, we expected that making if-then plans enhance processing efficiency of critical compared to non-critical items. With respect to the DSTP model, inducing response conflict in the form of incongruent stimuli should increase the importance of selective attention that differentiates between the response-relevant and the distracting information. Accordingly, effects on processing efficiency may show up in drift rates of the late stage of stimulus selection ($\mu_{RS2}$) and/or Phase 2 of response selection ($\mu_{RS1}$) in addition to the early stage of stimulus selection (reflected by the drift rate $\mu_{RS1}$). As in Experiment 1, we assumed that if-then plans cause no speed-accuracy tradeoff.

**Method**

**Participants**

Thirty students from the University of Konstanz were recruited using ORSEE (Greiner, 2015). One participant specified a wrong stimulus-response mapping and was thus excluded from the statistical analyses. The remaining sample comprised 29 (17 female) participants with a mean age of 24.2 years ($SD = 4.1$).

**Materials**

In this experiment we used Arial font numerals (2, 3, 4, and 5) and two arrows (< and >) as targets; the arrows were also used as flankers. As a consequence, the critical items (i.e., 2 or 5) never appeared as flankers. We mapped <, 2, and 4 to the left mouse button and >, 3, and 5 to the right mouse button. This resulted in a set of 6 congruent and 6 incongruent stimuli (see Table 3). All stimuli were presented equally often and the order of presentation was randomized at the individual level.

**Design**

The experiment adopted a 2 within (Item: critical vs. non-critical) × 2 within (Congruency: congruent vs. incongruent) full factorial design.

**Procedure**

The procedural details were similar to the previous experiments with a few exceptions. Participants ran through 12 practice trials and afterwards through
10 blocks of 120 trials (i.e., 1200 main trials per participant). As in Experiment 1, the fixation cross and the stimuli appeared at one of nine possible positions in an imaginary rectangle (i.e., at 40, 50, or 60% of the horizontal and vertical axis, respectively). We reduced the time between fixation cross and stimulus presentation from 600 to 300 ms and in turn added a 300 ms blank screen before the fixation cross appeared again.

Results

Goal and plan commitment

The reliabilities of the goal commitment ($\alpha = 0.74$) and the plan commitment ($\alpha = 0.62$) scales were adequate. Participants were committed to both the goal intention ($M = 5.4, SD = 1.1$) and the implementation intention ($M = 4.2, SD = 0.9$).

Data pre-treatment and analysis

Responses faster than 100 ms or slower than 1200 ms were excluded from data analysis (0.39% of all data). Error trials were removed from the response time analyses. Mean response times and error rates from trials in which either the digit 2 or 5 appeared as target were subjected to an ANOVA with Congruency (congruent vs. incongruent) and Item (critical vs. non-critical) as within-subjects factors. Trials with an arrow target were disregarded because arrows were also used as flankers and were perceptually different from the digits specified in the if-then plan. Trials with the digits 3 or 4 as target were also disregarded because we never assigned these digits as critical items. Preliminary analyses of the data revealed, however, that the digits 2 and 5 were generally easier to categorize than 3 and 4 (regarding both response times and error rates) independent of the if-then plan. Using data from these trials as an estimate of the non-critical item performance would have biased our results in favor of our hypotheses. Thus, only the digits 2 and 5 are referred to as critical and non-critical items.

Response times

The response time analysis (Figure 10 (a)) revealed a significant main effect of Congruency, $F(1,28) = 85.62, p < .001, \eta_p^2 = .754$. Responses were faster in congruent than in incongruent trials (433 versus 467 ms). The main effect of Item was not significant, $F(1,28) = 1.96, p = .173, \eta_p^2 = .065$. However, we found a significant interaction effect of Congruency and Item, $F(1,28) = 4.31, p = .047, \eta_p^2 = .133$. Although responses to critical items...
were faster than responses to non-critical items in congruent and incongruent trials, the difference was more pronounced in incongruent trials (congruent: 432 versus 434 ms; incongruent: 462 versus 473 ms). Follow-up analyses revealed that the difference between critical and non-critical targets reached significance only in incongruent trials, $F(1, 28) = 4.23, p = .049, \eta^2_p = .131$.

![Figure 10](image)

**Figure 10.** Mean response times (a) and mean error rates (b) as a function of Congruency and Item in Experiment 3. Error bars represent standard errors.

**Error rates**

The error rate analysis (Figure 10 (b)) revealed a significant main effect of Congruency, $F(1, 28) = 6.49, p < .001, \eta^2_p = .699$. Fewer errors were made in trials with congruent compared to incongruent flankers (4.0 versus 11.4%). All other main effects and interaction effects were far from being significant ($p$s > .75). Importantly, the error rate was numerically lower for critical items than for non-critical items (7.6 versus 7.8%). This indicates that faster responses for critical than non-critical items did not cause a speed-accuracy tradeoff.

**DSTP fitting procedure**

Similar to Experiment 1, we fit the DSTP model to our data (Figure 11). Again, we assumed symmetric boundaries for both response ($A = B$) and stimulus selection ($C = D$). Because of increased complexity of Experiment 3, though, we made several modifications to the modeling procedure. First, the
involvement of congruent and incongruent stimuli in Experiment 3 required the consideration of separate parameters for target and flanker components $\mu_t$ and $\mu_f$, respectively, at the early stage of stimulus selection. Accordingly, the drift rate $\mu_{RS1}$ in the Phase 1 of response selection was composed as sum of the parameters $\mu_t$ and $\mu_f$. Second, because critical as well as non-critical items were numerical targets, whereas the flankers were always uncritical arrows, we considered the possibility that processing differences between the two character types might have affected not only Phase 1, but also Phase 2 of response selection. Accordingly, we introduced separate drift rates $\mu_{RS2C}$ and $\mu_{RS2D}$ that captured the rate of response selection when the numerical target or an arrow flanker was chosen at the late stage of stimulus selection, respectively. Third, Experiment 3 made it plausible that behavioral effects of if-then planning are caused by a mixture of several processes rather than a single process as suggested in Experiment 1. Specifically, the larger stimulus set in Experiment 3 might have fostered enhanced stimulus-response links in addition to increased item accessibility. We therefore abstained from varying only one or two parameters across target conditions and estimated the effect of if-then plans on all parameters. As mentioned in Experiment 1, however, this procedure makes a simultaneous fit for the two item conditions impracticable, as the fit algorithm for a model with 16 free parameters would hardly converge. We therefore estimated separate parameter sets for the critical and non-critical item conditions.

Figure 11. Cumulative probability functions (a; CDFs) and conditional accuracy functions (b; CAFs) as a function of Congruency and Item in Experiment 3. Lines represent model estimates and data points represent observed data.
The resulting model versions for both the critical and non-critical item conditions had 8 parameters: drift rates for target and flanker components $\mu_{ta}$ and $\mu_{ba}$, respectively; a threshold parameter $A = B$ for response selection; rate $\mu_{SS}$ for late stimulus selection; a threshold parameter $C = D$ for late stimulus selection; rates $\mu_{RS2C}$ and $\mu_{RS2D}$ for response selection in Phase 2; and a non-decisional component $t_{er}$. Accordingly, these models comprised $df = (11 - 1) + (11 - 1) - 8 = 12$. As in Experiment 1, parameters were estimated with a jackknife procedure (Gray & Schucany, 1972; Jackson, 1986; Mosteller & Tukey, 1977). Accordingly, variations of each parameter for critical and non-critical items could be tested for significance.

DSTP results

Figure 11 illustrates the DSTP fit results for CDFs and CAFs in Experiment 3. Average parameters for the DSTP fits are listed in Table 3. Separate ANOVAs for each parameter revealed significant differences between critical and non-critical items in drift rates $\mu_{ta}$ and $\mu_{ba}$ for the constituents of early response selection. If-then plans caused an increased drift rate for critical target items and a decreased drift rate for corresponding flanker items, pointing to improved sensory filtering.

In addition, $\mu_{SS}$ was higher for critical than for non-critical items, suggesting that if-then plans also enhanced the late stage of stimulus selection. This is compatible with our prediction that increased accessibility of the critical item specified in the if-part of the plan not only results from early sensory processing but also from improved late attentional selectivity.

Finally, the drift rates $\mu_{RS2C}$ and $\mu_{RS2D}$ for Phase 2 of response selection were higher for critical than for non-critical items. This is in line with our hypothesis that linking the critical item to a respective response in the then-part of the plan strengthens the association between critical item and response. Interestingly, the rate for Phase 2 of response selection was not only higher for critical compared to non-critical items when the target was chosen ($\mu_{RS2C}$), but also when a flanker item (arrow) was erroneously selected ($\mu_{RS2D}$). It seems that if-then plans generally improved the strength of response associations when a critical item was present.

Importantly, neither the differences in the non-decisional components $t_{er}$ nor those in the threshold parameters $A/B$ or $C/D$ were reliable. Together with the absence of a speed-accuracy tradeoff in the empirical data, the latter result confirms the notion that the effects of if-then plans are not based on modulations of response thresholds.
Table 5. Parameter estimates obtained by fitting the DSTP model to CDFs (correct responses) and CAFs (error rates) for critical and non-critical items in Experiment 3.

<table>
<thead>
<tr>
<th>Parameter Estimates</th>
<th>Target</th>
<th>Early selection</th>
<th>Late selection</th>
</tr>
</thead>
<tbody>
<tr>
<td>n.s.</td>
<td>0.273</td>
<td>0.132</td>
<td>0.597</td>
</tr>
<tr>
<td>CI</td>
<td>0.132</td>
<td>0.168</td>
<td>0.406</td>
</tr>
<tr>
<td>CI</td>
<td>0.143</td>
<td>0.132</td>
<td>0.269</td>
</tr>
<tr>
<td>CI</td>
<td>0.168</td>
<td>0.132</td>
<td>0.406</td>
</tr>
</tbody>
</table>

Note: The estimates represent mean values obtained by the Jackknife procedure. CI = critical item; NI = non-critical item; CI = critical item; NI = non-critical item. *p < 0.05; **p < 0.01; ***p < 0.001.

Parameters:
- CI = critical item
- NI = non-critical item
- CI = critical item
- NI = non-critical item
- CI = critical item
- CI = critical item

Target and non-critical items in Experiment 3.

Parameter estimates obtained by fitting the DSTP model to CDFs (correct responses) and CAFs (error rates) for critical and non-critical items in Experiment 3.
Discussion

The results of Experiment 3 confirm our previous findings in both the behavioral and the DSTP analyses. We observed better performance for critical compared to non-critical items in incongruent trials. The lack of significance in congruent trials might reflect a ceiling effect owing to the very low mean response time of 434 ms in these trials. We observed a similarly low average response time only in Experiment 1 using a simplified flanker task without response conflict. Thus it is plausible to assume that participants were not able to push performance below these response times in the considerably more difficult task of Experiment 3, despite the use of if-then plans.

In line with our predictions, the introduction of response conflict increased the importance of the late stage of stimulus selection and of the Phase 2 of response selection in addition to the early stage of stimulus selection (see Experiment 1). Accordingly, the DSTP fits revealed significantly higher drift rates $\mu_{RS1}$, $\mu_{SS}$, and $\mu_{RS2}$ for critical compared to non-critical items, whereas neither the non-decisional component $t_{er}$ nor the response thresholds A/B and C/D were affected. This is compatible with the DSTP fits of Experiment 1 and supports the idea that the effects of if-then plans are neither a consequence of response threshold modulations, nor a mere speed-up of motor processes. Instead, they seem to enable individuals to enhance their efficiency of stimulus processing as indicated by significant drift rate effects in early as well as in late stages of decision making.

General Discussion

Research on information processing largely agrees that the trade-off between speed and accuracy sets general boundaries to the benefits of different response strategies: speed-emphasizing strategies result in lower response accuracy and vice versa (e.g., Fitts, 1966; Schouten & Bekker, 1967; Wickelgren, 1977; Woodworth, 1899). This has led to the prevalent assumption that strategic enhancements of processing efficiency in the form of increasing speed or accuracy without tradeoff are rather unfeasible (e.g., Heitz, 2014; Luce, 1986). Consequently, unequivocal evidence for a response strategy augmenting the efficiency of information processing does have great theoretical and practical relevance. The present research capitalized on the self-regulation strategy of making if-then plans (i.e., implementation intentions; Gollwitzer, 1993, 1999, 2014) as a promising candidate to provide such evidence. In line with our predictions, we observed faster responses to critical items specified in an if-then plan, as compared to non-critical items. We replicated
this result across three experiments using different variations of the flanker task and showed that the effect was never accompanied by a speed-accuracy tradeoff. This pattern strongly suggests that making if-then plans reflects a suitable strategy to improve the efficiency of information processing. Further support for this conclusion came from formal sequential sampling modeling. Fits of the dual-stage two-phase (DSTP; Hübner et al., 2010) model indicated that if-then plans increased the efficiency of early stimulus selection ($\mu_{RS1}$) in a setup that mainly required sensory processing (Experiment 1), whereas a setup with additional demands on attentional selectivity (Experiment 3) revealed effects on early and late stimulus selection ($\mu_{RS1}$ and $\mu_{SS}$) as well as on Phase 2 of response selection ($\mu_{RS2}$). Together, these findings provide converging evidence that individuals can indeed enhance processing efficiency given an effective response strategy such as making if-then plans.

Mapping the If-then Planning Effects to Components of the DSTP Model

We had chosen the self-regulation strategy of if-then planning because it has previously been demonstrated to enhance the accessibility of critical items and to automatize the initiation of a respective response (Gollwitzer & Sheeran, 2006). Accordingly, we expected that planning effects manifest systematically in the parameters of the DSTP model. Indeed, the results of Experiments 1 and 3 support a meaningful match between cognitive processes underlying if-then plans and DSTP model parameters.

First, improved accessibility of the critical item specified in the if-part of an implementation intention is assumed to originate from enhanced perceptual processing reflected by early and late stages of stimulus selection in the DSTP model. Specifically, the if-part may improve item accessibility through an early processing advantage because the mental representation of a critical item is stronger (e.g., more pre-activated) compared to that of a non-critical item. In the DSTP model, this would be expressed as an enhanced sensory filter in the early stage of stimulus selection, and therefore as an increase in the rate of evidence accumulation (i.e., drift rate) in Phase 1 of response selection $\mu_{RS1}$ (i.e., the direct output of the early stage of stimulus selection). Further, it is possible that improved item accessibility relies on the speeded categorization of the critical item and thus on late attentional selectivity. In the DSTP model, such a recognition advantage would be captured by the drift rate $\mu_{SS}$ for the late stage of stimulus selection.

Second, strategic automaticity of the instrumental response specified in the then-part of an implementation intention is assumed to reflect an en-
hanced link between the critical item and the associated response. Accordingly, selection and identification of the critical item immediately trigger the initiation of the relevant response. In the DSTP model, item-response associations are expressed as rate of response selection in Phase 2, ascribing the then-part effect to an increase of the drift rate $\mu_{RS2}$. Another possibility is that the strengthened if-then link also affects the speed of motor commands or early response selection.

Compatible with these considerations, we observed a higher drift rate $\mu_{RS1}$ for critical targets in a setup which primarily relied on sensory processing (Experiment 1) suggesting that heightened accessibility of the critical item maps to the efficiency of early stimulus selection in the DSTP model. Further, implementation intention effects on the drift rates $\mu_{SS}$ and $\mu_{RS2}$ under increased task demands (Experiment 3) indicate that the if-then association might be primarily captured by late stimulus selection and Phase 2 of response selection. Finally, the insignificant effects on $t_{er}$ in both Experiments 1 and 3 speak against a motor-speed-up effect.

Although the DSTP model was not developed in the context of theoretical deliberations on implementation intentions, our results suggest a systematic relation between if-then plans and DSTP parameters. This correspondence between the approaches has important implications for research in the domains of implementation intentions and sequential sampling models.

**Implications**

Beyond supporting the main conclusion that individuals can strategically enhance information processing efficiency for specific stimuli, our findings show benefits of combining insights from two different research areas: research on implementation intentions, which has primarily been established in the context of social and motivational phenomena, and research on sequential sampling modeling of performance in conflict tasks, which has been developed to explain basic perceptual and attentional mechanisms in information processing and mental control.

**Implications for implementation intention research**

The present research corroborates prior findings on the processes mediating if-then planning effects on performance (Gollwitzer & Oettingen, 2011) by mapping them onto parameters of a sequential sampling model. Our results further indicate that these processes are moderated by task requirements. While implementation intention effects were mediated by enhanced item accessibility when the task primarily required sensory processing (Experiment
1), the association strength between the critical item and the respective response emerged as additional mediator when task demands became more complex (Experiment 3).

Moreover, adopting a sequential sampling approach permits new perspectives on the processes underlying implementation intentions. First, increased accessibility of a critical item specified in the if-part seems to promote enhanced information processing during early or late stimulus selection. Our findings suggest however that task complexity is an important moderator: in non-conflict tasks with one-to-one stimulus-response mapping, early stimulus selection is crucial, whereas in conflict tasks with many stimuli and a more complex mapping late stimulus selection comes into play. Second, prior research left open whether the automatic initiation of the response in the then-component results from a heightened associative strength of the then-plan link or from a speed-up in motor commands. Our findings suggest that the first process is more important than the latter.

Implications for sequential sampling approaches

Research using sequential sampling models to delineate cognitive mechanisms has provided evidence that the efficiency of information processing (as indexed by the drift rate) is modulated by task difficulty and by largely invariant individual capacities, whereas response thresholds and starting points of evidence accumulation are under strategic control (Ratcliff, 2002; Voss, Rothermund, & Voss, 2004; Wagenmakers, Ratcliff, Gomez, & McKoon, 2008, but see, e.g., Dambacher & Hübner, 2013, 2015; Rae, Heathcote, Donkin, Averell, & Brown, 2014). While this prevalent view may hold in many circumstances, our results demonstrate that strategic control of processing efficiency is indeed possible and should therefore be considered in approaches using sequential sampling models.

Our study is also a validation of the dual-stage two-phase (DSTP; Hübner et al., 2010) model of selective attention. Extensive research has shown that implementation intention effects are mediated by enhanced item accessibility and the automatic initiation of a goal-directed response (Gollwitzer & Sheeran, 2006). These processes can be plausibly mapped to components of the DSTP model, and the parameter estimates in Experiments 1 and 3 were sensitive to both processes.
Alternative Means to Enhance the Efficiency of Information Processing

The present research demonstrates that individuals can strategically enhance their processing efficiency. Here, we used if-then plans as response strategy because they are well-established and effective tools for self-regulation and action control (for reviews see Gollwitzer, 2014; Gollwitzer & Sheeran, 2006). Yet, it should be mentioned that the observed effects are not necessarily unique to implementation intentions, but might also pertain to alternative strategies.

In particular, financial incentives have been demonstrated to improve performance by increasing attentional effort (Kleinsorge, 2001; Sarter et al., 2006). Hübner and Schlösser (2010), for instance, showed that incentives lead to the mobilization of attentional effort and result in better flanker task performance. Nevertheless, the generalizability of such findings appears limited as, among other factors (Bonner & Sprinkle, 2002), positive effects depend on the used incentive scheme; whereas incentivizing response speed yields considerable performance improvements, an emphasis on accuracy is not effective (Dambacher et al., 2011). As another candidate, repeated practice can serve as a strategy to improve performance over time. However, research indicates that positive effects on performance are rather a mixture of various psychological processes, including response thresholds and non-decision time beyond the effects on processing efficiency (Dutilh, Vandekerckhove, Tuerlinckx, & Wagenmakers, 2009). In summary, the present research is the first demonstration that response strategies (i.e., if-then plans) can have direct effects on the efficiency of information processing; still we encourage future research on comparing alternative ways of enhancing processing efficiency.

Further Considerations

Model choice and parameter interpretation

Regarding our adoption of a sequential sampling approach, there are two important considerations regarding model choice and parameter interpretation. First, there is an ongoing debate about whether information processing in conflict tasks is better described by discrete (such as DSTP) or continuous (such as shrinking spotlight) models of selective attention (Hübner et al., 2010; White, Ratcliff, & Starns, 2011). We decided for the discrete DSTP model because it outperforms continuous models in various task setups (e.g., Hübner, 2014), especially in those similar to the present setups (i.e., long response-stimulus intervals and response conflict, Hübner & Töbel, 2012).
Further, the DSTP model lends itself well to an analysis of if-then plan effects because it readily distinguishes their stimulus-related (i.e., cognitive accessibility) and response-related (i.e., associative strength) processes by estimating distinct drift rates for early and late response selection. Continuous models, on the other hand, estimate a single drift rate to describe the efficiency of information processing and can thus not make this distinction. Thus, although continuous models would presumably yield analogous overall conclusions (i.e., an increased drift rate in critical versus non-critical trials), we have chosen the DSTP model to adequately capture the structure of if-then plans.

Second, sequential sampling models often invite researchers to make strong assumptions about the mapping between parameters and cognitive processes, and one may ask whether such inferences are valid. Research so far gives an affirmative answer: systematic variations in experimental setups cause predictable changes in parameter estimates (e.g., Ratcliff, 2002; Voss et al., 2004). In particular, research on the DSTP model has shown that its parameters capture the relative contributions of early and late selection processes (Hübner et al., 2010). We thus feel confident to interpret the observed changes in the DSTP drift rates as valid indicators for information processing efficiency.

**Limits of strategically enhancing processing efficiency**

Across all of the reported experiments we showed that if-then plans enable participants to exert control over their processing efficiency. Still, two limitations of such control evinced. First, participants in Experiment 2 did not restrict the more efficient processing to trials in which the critical item appeared at the central target position. This stresses the bottom-up stimulus-controlled nature of implementation intentions (Gilbert et al., 2009), and is well in line with previous findings showing that the specified situational items manage to involuntarily tap attentional and perceptual resources (Achtziger et al., 2012; Janczyk, Dambacher, et al., 2015; Wieber & Sassenberg, 2006).

Second, the observed efficiency improvements of about 10 ms are relatively small. However, Experiment 2 suggests that some participants may have applied the if-then planning strategy to non-critical items as well. Moreover, the fitting of the DSTP model required a large number of trials, such that training improvements may have covered more sizeable implementation intention effects (Dutilh et al., 2009). Considering both of these arguments makes the small observed effect sizes appear less surprising. Moreover, it is important to recognize that the main purpose of the present research was to test whether individuals are in principle able to strategically enhance the ef-
efficiency of information processing, and the observed effect sizes are sufficient to provide this proof of concept.

**Summary and Conclusion**

The present study investigated whether individuals who make if-then plans (i.e., implementation intentions) can increase the efficiency of information processing. Across three experiments using different variations of the flanker task, responses to critical items specified in an if-then plan were faster than responses to non-critical items. The absence of a drop in accuracy indicated that this speed-up indeed reflected enhanced efficiency. Fits of the dual-stage two-phase (DSTP) sequential sampling model confirmed this view. The resulting parameters for critical compared to non-critical items revealed higher drift rates for early stimulus and response selection in a setup without response conflict, and additional improvements of the rates for late stimulus and response selection in a response-conflict setup. Together, these findings suggest that suitable response strategies may well enable individuals to exert control over the efficiency of information processing.
Research Paper III

Social Value Orientation Moderates the Effects of Intuition versus Reflection on Responses to Unfair Ultimatum Offers

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Abstract

We investigated whether social value orientation (SVO) moderates the effects of intuitive versus reflective information processing on responses to unfair offers. We measured SVO one week prior to an ultimatum game experiment in which participants made the plan to adopt an intuitive or a reflective mode of processing (intuitive and reflective condition, respectively), or made no such plans (control condition), before deciding to accept or reject a series of 10 ultimatum offers including very low (unfair) ones. Participants with rather high (prosocial) SVO scores were more likely to accept unfair offers in the reflective than the intuitive condition. This effect also evinced for a subset of selfish individuals; however, the majority with rather low (selfish) scores made similar decisions in both conditions. This pattern of results suggests that SVO moderates the effects of intuitive versus reflective modes of processing on responses to low ultimatum offers.
Introduction

Many people dislike being treated in an unfair manner, and they are willing to spend resources to punish those who treat them unfairly (e.g., Camerer & Thaler, 1995; Fehr & Gächter, 2000, 2002; Kahneman, Knetsch, & Thaler, 1986; Rabin, 1993). This preference has often been analyzed with the ultimatum game (Güth, Schmittberger, & Schwarze, 1982; see Güth & Kocher, 2014, for review). In this two-player game, the proposer receives a certain amount of money and offers the responder an allocation of this amount. If the responder accepts the offer, the amount is allocated as proposed; otherwise both players receive no money. Assuming common knowledge of rationality and selfishness, responders will accept any positive offer and proposers will make the smallest possible offer. In contradiction to this account, however, proposers commonly make offers in the range of 40 to 50% of the money, while many responders reject low offers below 20% (review by Camerer, 2003). The large offers made by proposers can at least partially be explained by strategic considerations (Bolton & Zwick, 1995), but responder rejections of low offers are purely non-strategic and hence interpreted by most researchers as indicating a preference for being treated fairly (Fehr & Gächter, 2000).

In recent years, it has been debated whether and how the way people process information in the ultimatum game affects the decision to accept or reject unfair offers. This question lies at the heart of dual-process models which distinguish between two modes of information processing, an intuitive and a reflective one, that govern decision making (e.g., Alós-Ferrer & Strack, 2014; Evans, 2008; Haidt, 2001; Kahneman, 2011; Strack & Deutsch, 2004; Weber & Johnson, 2009). The intuitive mode is assumed to concert processes that are fast, efficient and affect-based, permitting swift and effortless responses. The reflective mode, in contrast, is thought to rely on time and cognitive resources, affording prudent and considered decisions. But how does adopting one or the other mode of processing affect responses to unfair offers as observed in the ultimatum game? Are people more likely to accept unfair offers when they reflect upon their decisions, or when they rely on their intuition? A growing body of literature addresses this question and consistently reports that adopting different modes of processing is consequential for the decision to accept or reject unfair offers. However, the nature of these consequences is still an open question.
Effects of Adopting Intuitive versus Reflective Modes of Processing on Responses to Unfair Ultimatum Offers

On the one hand, there is considerable research that relates low acceptance rates for unfair offers to negative affect (e.g., anger and disgust) or scarce cognitive resources, both characteristic of an intuitive mode of processing. For instance, acceptance decisions have been observed to correlate negatively with self-reported feelings of anger (Pillutla & Murnighan, 1996) as well as with activity in brain areas that are associated with intuitive processing (e.g., Sanfey, Rilling, Aronson, Nystrom, & Cohen, 2003; Tabibnia, Satpute, & Lieberman, 2008). Speaking to the causal role of negative emotions for these effects, providing people with emotion-regulation strategies increases acceptance rates (e.g., Kirk, Gollwitzer, & Carnevale, 2011; van ’t Wout, Chang, & Sanfey, 2010), whereas depleting the resources required for self-regulation reduces them (Achtziger, Alós-Ferrer, & Wagner, 2014, Exp. 2).

Additional supportive evidence comes from studies in which the cognitive resources available to participants were strained, tantamount to promoting intuitive modes of processing which, in contrast to reflective modes, do not require such resources. For instance, forcing people to make their decisions in short time resulted in lower acceptance rates of unfair offers compared to imposing rather loose time constraints (Sutter et al., 2003), whereas people obliged to pause before making their decision exhibit higher acceptance rates compared to situations without such a delay (Grimm & Mengel, 2011; Neo et al., 2013). Taken together, these studies yield profound support for the assumption that adopting a reflective mode of processing increases the likelihood of accepting unfair offers, as compared to an intuitive mode.

Interestingly, there are several studies with opposite results, demonstrating that unfair offers are less likely to be accepted in reflective than intuitive modes of processing. For instance, Knoch, Gianotti, Baumgartner, and Fehr (2010) have shown that baseline activity in prefrontal cortex areas is negatively correlated with acceptance rates for unfair offers. As lower baseline activity in these areas is commonly associated with less reflective processing (E. K. Miller & Cohen, 2001), this finding suggests that people intuitively act in a selfish manner and accept unfair offers. If the relation is causal, derogations of the prefrontal cortex should lead to an increase in acceptance rates. This hypothesis was supported by applying repeated transcranial magnetic stimulation (rTMS) to disrupt the prefrontal cortex, causing responders to accept more unfair offers (Knoch et al., 2008; Knoch, Pascual-Leone, Meyer, Treyer, & Fehr, 2006; van ’t Wout, Kahn, Sanfey, & Aleman, 2005). Related evidence is provided by two studies in which reflective processing was reduced by depleting self-regulatory resources (Achtziger et al., 2014, Exp. 1)
or instructing participants to make quick decisions rather than thoughtful ones (Hochman et al., 2015); both manipulations promote an intuitive over a reflective mode of processing and rendered participants more likely to accept unfair offers.

At the bottom line, all of these studies share the observation that adopting an intuitive versus a reflective mode of processing has consequences for the decision to accept unfair offers in the ultimatum game, but the nature of these consequences remains puzzling. How can we move on and address such inconsistent findings? A promising approach is to identify moderators of intuitive versus reflective processing effects on responses to unfair offers.

**The Moderating Role of Social Value Orientation (SVO)**

In the present research we turned to the concept of social value orientation (SVO; Messick & McClintock, 1968; Murphy & Ackermann, 2014; van Lange, 1999), a simple measure of prosociality that is likely related to the decision to accept or reject unfair offers in an ultimatum game (see below). SVO captures preferences for allocating resources between oneself and another person, and two main types of preferences are commonly distinguished (Au & Kwong, 2004; Bogaert, Boone, & Declerck, 2008). Individuals with cooperative (prosocial) preferences are willing to sacrifice their own resources to establish equal allocations and/or to maximize the mutual benefit. Individuals with individualistic (selfish) preferences, in contrast, solely focus on their personal benefits, trying to maximize their own resources and largely ignoring consequences for others. Besides these two main types, there are also small groups of people with either competitive preferences (trying to obtain more resources than the other person, even if this comes at an own cost) or altruistic preferences (trying to maximize the resources of the other, even when this requires to forfeit own benefits).

The preferences reflected by SVO have been associated with patterns of social interactions from early childhood to old age (e.g., van Lange, Otten, De Bruin, & Joireman, 1997), and they are ubiquitous in everyday life. For instance, differences in SVO govern pro-environmental behavior (Gärling, Fujii, Gärling, & Jakobsson, 2003), political ideologies (van Lange, Bekkers, Chirumbolo, & Leone, 2012), the willingness to sacrifice in close relationships (van Lange, Agnew, Harinck, & Steemers, 1997), the readiness to help others (van Lange, Schippers, & Balliet, 2011), and the generosity of charitable donations (Bekkers, 2007). SVO is rather stable over time (Bogaert et al., 2008; Murphy, Ackermann, & Handgraaf, 2011), and has consistently been shown to predict social decisions in experiments. In particular, prosocial individuals are more likely to cooperate in social dilemmas than selfish individuals (re-
views by Balliet, Parks, & Joireman, 2009; Bogaert et al., 2008; van Lange, Joireman, Parks, & Van Dijk, 2013).

In sum, SVO is a simple measure of prosociality, and as such probably associated with the response to unfair ultimatum offers. How it is related to the decision to accept or reject unfair offers is, however, not a priori clear. Prosocial responders could be unconditionally kind, forgiving unfair proposers and accepting their low offers; alternatively, they might be motivated to enforce a social norm to act fairly and thus reject unfair offers. Selfish responders might accept unfair offers because doing so maximizes their profit; it is, however, also conceivable that they grudge unfair proposers their larger share of money, and this envy could cause them to reject low offers. Ultimately, it is an empirical question how differences in SVO are incorporated in responses to unfair offers.

To our knowledge, there have been two studies addressing this issue so far. One study (Haruno, Kimura, & Frith, 2014) observed that people with prosocial preferences are less likely to accept unfair offers than those with selfish preferences under varying degrees of cognitive load. This result is consistent with the view that prosocial, but not selfish people, intuitively dislike unequal allocations (e.g., Cornelissen, Dewitte, & Warlop, 2011; Haruno & Frith, 2010; Haruno et al., 2014; Kuss et al., 2015) and are thus less likely to accept low offers which, by construction, would result in rather unequal allocations if accepted. This interpretation is, however, hard to reconcile with another study (Karagonlar & Kuhlman, 2013) that did not impose load and found selfish people to be less likely to accept an unfair offer compared to prosocials. The authors attribute their observation to differences in emotion regulation: whereas selfish people might fail to regulate their anger and spite when facing unfair offers and thus reject, prosocials accept the unfair offer because they succeed in regulating such negative emotional responses.

In sum, there is scarce and conflicting evidence on how differences in SVO are reflected in responses to unfair offers, making it difficult to derive a specific hypothesis about the association between SVO and responder decisions in the ultimatum game. However, by systematically analyzing this association in both an intuitive and a reflective mode of processing, the present research can potentially contribute to the current debate.
Methods

Participants
We recruited a total of 192 student participants using the online recruitment system ORSEE (Greiner, 2015). Of these participants, 32 were assigned to the role of a proposer and thus did not contribute to the dataset. 160 participants were assigned to the role of a responder; we did not obtain data from 6 participants due to hardware failure. Ten responders did not want to adopt the suggested mode of information processing (see below; 7 in the reflective and 3 in the intuitive condition) but their decisions are nevertheless included in the analyses to prevent self-selection bias and permit causal inferences (i.e., we used an intention-to-treat approach; Hollis & Campbell, 1999). This results in a final sample size of 154 participants (69 female; age: $M = 23.22$, $SD = 2.81$). The experiment was programmed and conducted with the software z-Tree (Fischbacher, 2007).

Materials and Procedure
Screening session
In the screening session we measured participants’ social value orientation (SVO) with the Slider Measure (Murphy et al., 2011), a well-validated tool for assessing SVO (Murphy & Ackermann, 2014). The Slider Measure comprises 6 items with 9 different allocation options lying on a specific line in the plane of one’s own payoff and the other’s payoff (e.g., [50,100], [54,98], $\ldots$, [81,87], [85,85]). By choosing one of these options, participants allocate the specified points between themselves and a randomly selected other participant. For instance, participants choosing a [85,85] option assigned 85 points both to themselves and to the other participant. Based on these six items, we calculated a continuous SVO score. Participants could in principle be categorized according to their SVO score as exhibiting competitive, individualistic (selfish), cooperative (prosocial), or altruistic social preferences. However, using the continuous score is strongly recommended over relying on the nominal categories (Fiedler, Glöckner, Nicklisch, & Dickert, 2013; Murphy & Ackermann, 2014), and we therefore used the score in all the statistical analyses. Higher SVO scores correspond to more prosocial preferences; lower scores on the other hand represent more selfish preferences. We incentivized the SVO Slider measure but did not inform participants about the results in order to avoid carry-over effects to the experimental session (e.g., compensating for a low payment).
It has recently been shown that preferences for reflective information processing are negatively associated with acceptance decisions in ultimatum games (Mussel, Göritz, & Hewig, 2013). Because we wanted to randomly assign participants to different mode of processing conditions later in the experiment, we thus aimed for a check that participants did not differ in their preferred processing modes between these conditions. To this end, we assessed participants’ processing preferences using a German version (Keller, Bohner, & Erb, 2000) of the Rational Experiential Inventory (REI; Epstein, Pacini, Denes-Raj, & Heier, 1996). The REI is a 29-item self-report measure with two subscales assessing intuitive (e.g., “I trust my initial feelings about people,” α = 0.86) and reflective (e.g., “I don’t like to have to do a lot of thinking (reversed),” α = 0.81) modes of processing, respectively. Participants indicated how much they agreed with each statement on 7-point Likert scales ranging from 1 (do not agree) to 7 (totally agree), and we averaged their answers into intuitive and reflective preference scores.

Experimental session

The experimental session took place one week after the screening session to assure that assessing SVO and the preferred mode of processing would not affect decisions in the ultimatum game. Participants read the ultimatum game instructions and then worked on a practice trial showing the relevant decision screens for proposers and responders. Afterwards, they were told about their role in the games (i.e., either proposer or responder).

Processing strategy. Before they started working on the ultimatum games, proposers and responders in the control condition learned that they would engage in a 15 min task that was neither incentivized nor related to the ultimatum game (i.e., they searched letters in a nonsense text). These participants were not provided with a rationale for this task; they neither received any information on what other participants did during the 15 min time period. Responders in the intuitive and the reflective condition, in contrast, received a brief description of either the intuitive or reflective mode of processing plan, and we requested them to choose between the respective plan and the neutral task. They were given this choice to ensure that they would not feel patronized by the instructions. Participants did choose between either intuitive versus neutral or reflective versus neutral; they never had the choice between the two plans. Those who opted for a mode of processing plan (90.2% of the participants who were given the choice; 94.2% in the intuitive and 86.0% in the reflective condition) then proceeded with adopting the plan, whereas the remaining participants received the neutral task. All
participants worked for a fixed 15 min time period on the documents they received.

In the intuitive condition, participants were instructed to think about pondering at length about the decisions as a potential obstacle for achieving their goals in the upcoming decisions, and made a plan specifying how to overcome this obstacle: “If I start pondering at length, then I will tell myself: Listen to your guts!” Analogously, participants in the reflective condition thought about acting in a hasty way as an obstacle and made the plan: “If I start acting in a hasty way, then I will tell myself: Use your brain!” This method of planning out how to respond when encountering an obstacle for goal achievement is known in psychology as “mental contrasting with implementation intentions” (Gollwitzer, 1999; Oettingen, 2012; Oettingen et al., 2001, 2013); it enables people to recognize the specified obstacle immediately as it emerges and to automatically initiate the pre-specified response. In the present research, we used this strategy to prepare participants to strategically switch to an intuitive versus reflective mode of processing as soon as they found themselves pondering at length or acting in a hasty way, respectively.

**Ultimatum game.** After the 15 min had elapsed, participants proceeded with playing 10 ultimatum game rounds. In each round, we presented them two allocations of 20 points: a fixed benchmark allocation yielding 9 points for the responder and 11 points for the proposer (i.e., a [9,11] allocation), and an alternative allocation favoring the proposer more strongly (e.g., a [3,17] allocation). One of these allocations was then offered to them and they could accept or reject this offer. In case of a rejection, both players received 0 points, otherwise the proposed allocation was implemented. Both the responder and the proposer received feedback about the outcome at the end of each round.

In each experimental session we had twenty responders and four proposers. In two rounds, the offer was made by one of the proposers (following a perfect stranger protocol) who could choose between the [9,11] benchmark allocation and a randomly generated alternative allocation that would have given them a higher payoff (e.g., a [3,17] allocation). In the remaining rounds the offer was selected from a pre-determined sequence of allocations ([9,11], [6,14], [2,18], [9,11], [3,17], [9,11], [1,19], and [4,16]) (see Sutter et al., 2003, for a similar procedure). This was done to ensure that each responder would experience a sufficiently high number of low offers, as these were of primary interest in the present research. At the same time, our design enabled us to include proposals by human proposers—a feature that is integral for eliciting
rejections of low offers (e.g., van 't Wout, Kahn, Sanfey, & Aleman, 2006). Note that participants were not deceived in our study; we informed them about the existence of computer-generated offers, however without detailing the exact share of these offers.

**Questionnaires.** Prior studies in the domain of ultimatum games have shown that unfair offers elicit feelings of anger and spite (e.g., Pillutla & Murnighan, 1996), so we checked whether our implementation of the ultimatum game produced such negative affect as well. Immediately after the ultimatum game decisions, we therefore assessed participants’ experienced affect with the 20-item Positive and Negative Affect Schedule (PANAS; Watson, Clark, & Tellegen, 1988). In this self-report measure, participants indicate the extent to which they experience 10 positive (e.g., excited, enthusiastic, proud; $\alpha = 0.85$) and 10 negative (e.g., upset, guilty, ashamed; $\alpha = 0.87$) emotions on a 5-point Likert scale (1 = *very slightly or not at all*, 5 = *extremely*). We averaged the answers into scores for positive and negative affect, respectively, to assess overall experienced affect. Importantly, the PANAS also includes some items that are specifically related to feelings of anger and spite (e.g., feeling upset) that we could use to check the success of our fairness manipulation in the ultimatum game.

We also wanted to check that participants in the intuitive and the reflective condition understood and adopted their respective mode of processing plans. To probe their understanding, we presented three pairs of statements (i.e., six items altogether) to assess the degree to which these participants in the intuitive and reflective condition felt that their plan required them to respond slowly, to think carefully, and to make the most beneficial decisions. Because in all three pairs the statements were essentially reversed (e.g., “I felt instructed to make my decisions slowly” versus “I felt instructed to make my decisions quickly”), we reverse-scored one of the items and then averaged across the two scores. This resulted in three composite scores indicating the degree to which participants understood their respective processing manipulations. We also measured how committed participants were to adopt the assigned mode of processing with a 4-item commitment scale (e.g., “I was strongly committed to the plan,” $\alpha = 0.75$) that has been validated for research purposes (Klein et al., 2001). We averaged these items into a single commitment score.
Analysis

The data was analyzed with the statistical software R (R Core Team, 2014) and visualized with the package `ggplot2` (Wickham, 2009). When regression results are reported, statistical inference is based on robust standard error estimates clustered on the responder level (154 clusters). We coded offers of three points or less (i.e., ≤ 20% of the available 20 points) as unfair, because offers of this size are commonly rejected by many responders (Camerer, 2003). Higher offers were coded as fair. The main dependent variable in the ultimatum game is whether an offer was accepted or rejected; however, we also measured response times as an additional manipulation check for our mode of processing manipulation.

Screening Session

The overall distribution of SVO scores ($M = 18.86$, $SD = 13.61$) is depicted in Figure 12. Eighty-seven participants were classified as selfish (intuitive: 31, control: 28, reflective: 28), 65 as prosocial (intuitive: 20, control: 23, reflective: 22), 2 as competitive (intuitive: 1, control: 1, reflective: 0), and none as altruistic. The SVO types were evenly distributed across the experimental conditions (Fisher’s exact test, $p = .900$). The analysis of the Rational Experiential Inventory revealed that participants generally preferred intuition ($M = 4.93$, $SD = 0.85$) over reflection ($M = 4.24$, $SD = 0.73$), $t(153) = 6.91$, $p < .001$. Importantly, we found no differences between the processing conditions regarding the preferences for intuition or reflection, $F’s < 1$.

Manipulation Checks

Understanding and adopting the processing plans. Our data suggest that participants understood and adopted their respective modes of processing. Compared to intuitive participants, reflective participants felt more required to decide slowly ($M = 5.28$, $SD = 0.19$ versus $M = 2.22$, $SD = 0.15$), $t(90) = 12.81$, $p < .001$ and to think carefully ($M = 5.45$, $SD = 0.20$ versus $M = 2.99$, $SD = 0.21$), $t(90) = 8.46$, $p < .001$, and they felt slightly more prompted to make the most beneficial decisions ($M = 5.20$, $SD = 0.19$ versus $M = 4.77$, $SD = 0.19$), but this difference was not significant, $t(90) = 1.59$, $p = .114$. Moreover, participants in the intuitive ($M = 4.04$, $SD = 1.52$) and the reflective ($M = 4.39$, $SD = 1.52$) condition were similarly committed to act on their plans, $t(90) = 1.14$, $p = .258$, indicating that they tried to adopt the respective mode of processing.
**Response times.** Rather than planning to make fast versus slow decisions, participants made plans to rely on their gut feelings versus their reflective thought, and yet they associated the former with making faster decisions than the latter (see above). If participants actually made faster responses, we expect differences in response times to show up primarily for responses to unfair offers, as these pose a conflict between acceptance and rejection decisions and thus might give rise to the obstacles of finding oneself pondering at length or acting hastily.

We found some support for this idea, as we observed faster responses to unfair offers among intuitive ($M = 6.98, SD = 3.95$) compared to reflective participants ($M = 8.41, SD = 5.93$), illustrated in Figure 13. To test this observation, we regressed response times on the effects of condition and fairness, as well as their interaction effect. The contrast of intuitive versus reflective participants approached significance when the offer was unfair, $\beta = 1.42$, $t = 1.93$, $p = 0.054$, but was clearly insignificant when the offer was fair, $\beta = 0.54$, $t = 1.02$, $p = 0.308$, resulting in a marginally significant interaction effect of fairness and condition, $\beta = -0.88$, $t = 1.69$, $p = 0.091$.

This pattern of results is consistent with the structure of the processing plans. Considered jointly with the questionnaire analysis, the response time analysis suggests that participants understood, adopted, and acted upon their assigned processing plans.
Affect. Overall, participants reported more positive ($M = 2.42$, $SD = 0.74$) than negative affect ($M = 1.80$, $SD = 0.71$), $t(153) = 8.29$, $p < .001$. However, this finding is hardly surprising given that the PANAS scales cover a broad range of affective states, many of them probably irrelevant in the context of ultimatum games, and we therefore identified three items that were more specifically related to anger and spite (i.e., feeling upset, hostile, and irritable)\textsuperscript{8}. Participants scored significantly higher on these items ($M = 2.41$, $SD = 0.09$) than on the other items of the negative affect scale, $t(153) = 10.45$, $p < .001$, indicating that the unfair offers indeed induced feelings of anger and spite. We found no differences between the mode of processing conditions with regard to these feelings, $F < 1$.

Responder Decisions

About 2/3 of all offers were accepted in the experiment. We analyzed responder decisions (coded 1 if the offer was accepted, 0 otherwise) using several logistic regressions with robust standard errors clustered on the responder level (154 clusters). As illustrated in Figure 14, low offers of $\leq 3$ points were much less likely accepted than the remaining offers, $\beta = 3.35$, $z = 22.55$.

\textsuperscript{8}A parallel analysis of the items suggested 4 factors. The items “upset,” “hostile,” and “irritable” loaded highly on one factor (factor loadings $> .80$, the remaining items loaded with $< .50$) in an exploratory factor analysis with oblimin rotation.
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$p < .001$, corroborating the interpretation of these low offers as unfair. Moreover, participants in the reflective condition were more likely to accept offers than those in the intuitive condition, $\beta = 0.33, z = 2.31, p = 0.021$, with the control condition falling in between. This result indicates that the mode of processing affected responder decisions in a meaningful way.

![Figure 14. Average acceptance rates as a function of condition and fairness. Error bars represent standard errors of the mean.](image)

To test our hypothesis that SVO moderates the effects of adopting an intuitive versus a reflective mode of processing, we regressed responder decisions on the effects of condition and SVO, as well as their interaction effect. The results are shown in Table 6 separately for unfair and fair offers. When evaluating these regressions, note that we mean-centered the continuous SVO score such that lower-order effects not including the SVO score are conditional on the observed average SVO score of $M = 18.86$, rather than 0, thus rendering them more representative for the overall sample (following a recommendation by Aiken & West, 1990).

Not surprisingly, we observed only little variation in responses to fair offers (see Table 6). Participants in the reflective condition were marginally more likely to accept fair offers than those in the intuitive condition, $\beta = 0.47, z = 1.88, p = 0.060$. Neither the effect of SVO, $\beta = 0.005, z = 0.59, p = 0.554$, nor the interaction effect of condition and SVO, $\beta = 0.01, z = 0.68, p = 0.498$, reached conventional levels of significance, however.

In contrast, responses to unfair offers varied as a function of both condition and SVO (see Table 6 and Figure 15). Participants in the reflective condition were
Table 6. Logistic regression models for explaining responses to offers in the ultimatum game (1 = accept, 0 = reject). Baseline is an SVO score of 18.86 in the intuitive condition.

<table>
<thead>
<tr>
<th></th>
<th>Unfair Offers</th>
<th></th>
<th>Fair Offers</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Model 1</td>
<td>Model 2</td>
<td>Model 3</td>
<td>Model 1</td>
</tr>
<tr>
<td>Intercept</td>
<td>-1.90***</td>
<td>-1.47***</td>
<td>-2.23***</td>
<td>1.78***</td>
</tr>
<tr>
<td></td>
<td>(0.32)</td>
<td>(0.17)</td>
<td>(0.30)</td>
<td>(0.16)</td>
</tr>
<tr>
<td>Condition = Control</td>
<td>0.53</td>
<td>0.82*</td>
<td>0.04</td>
<td>0.47†</td>
</tr>
<tr>
<td></td>
<td>(0.42)</td>
<td>(0.41)</td>
<td>(0.23)</td>
<td>(0.23)</td>
</tr>
<tr>
<td>Condition = Reflective</td>
<td>0.82*</td>
<td>1.15**</td>
<td>0.47†</td>
<td>0.47†</td>
</tr>
<tr>
<td></td>
<td>(0.41)</td>
<td>(0.40)</td>
<td>(0.25)</td>
<td>(0.25)</td>
</tr>
<tr>
<td>SVO^a</td>
<td>-0.03*</td>
<td>-0.06**</td>
<td>-0.00</td>
<td>-0.02</td>
</tr>
<tr>
<td></td>
<td>(0.01)</td>
<td>(0.02)</td>
<td>(0.01)</td>
<td>(0.01)</td>
</tr>
<tr>
<td>Control × SVO^a</td>
<td>0.02</td>
<td></td>
<td>0.02</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.03)</td>
<td></td>
<td>(0.02)</td>
<td></td>
</tr>
<tr>
<td>Reflective × SVO^a</td>
<td>0.06*</td>
<td></td>
<td>0.01</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.03)</td>
<td></td>
<td>(0.02)</td>
<td></td>
</tr>
<tr>
<td>Num. obs.</td>
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<td>478</td>
<td>478</td>
<td>1062</td>
</tr>
<tr>
<td>Pseudo R^2</td>
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<td>0.04</td>
<td>0.09</td>
<td>0.01</td>
</tr>
<tr>
<td>L.R.</td>
<td>7.88</td>
<td>11.19</td>
<td>27.13</td>
<td>4.90</td>
</tr>
</tbody>
</table>

Note. Numbers in parentheses are robust standard errors clustered on the responder level (154 clusters).
^aMean-centered variable.
†p < .1.*p < .05. **p < .01. ***p < .001.
condition were significantly more likely to accept unfair offers than those in the intuitive condition, $\beta = 0.82$, $z = 1.97$, $p = 0.048$. Moreover, we observed a significant effect of SVO, $\beta = -0.03$, $z = 2.38$, $p = 0.017$, such that higher (i.e., more prosocial) SVO scores were associated with a lower likelihood of accepting offers. Finally, the difference between the intuitive and reflective condition was qualified by a significant interaction effect with SVO, $\beta = 0.06$, $z = 2.00$, $p = 0.045$. Specifically, higher SVO scores were associated with a lower probability of accepting unfair offers in the intuitive condition, whereas differences in SVO did not play out in the reflective condition.

To further scrutinize this result, we probed the difference between the intuitive and the reflective condition with regard to unfair offers across the entire range of SVO scores observed in our study. Specifically, we plotted the

Figure 15. The estimated acceptance rate for unfair offers as a function of SVO score and mode of processing condition.
log odds ratio of accepting an unfair offer when belonging to the reflective rather than to the intuitive condition as a function of SVO score in Figure 16, along with the 95% confidence interval. For instance, the log odds ratio was estimated to be 1.15 for participants with an average SVO score of 18.86 (see Table 6), tantamount to an approximately three times larger odds of accepting an unfair offer when belonging to the reflective rather than the intuitive condition (note that \( \exp(1.15) = 3.16 \)).

![Diagram](image.png)

**Figure 16.** The estimated log odds ratio (solid line) of accepting an unfair offer when belonging to the reflective rather than the intuitive condition as a function of SVO. The dashed lines correspond to the 95% CI.

Figure 16 presents the estimated log odds ratio across all SVO scores, permitting a full examination of the effects of adopting an intuitive versus reflective mode of processing. The difference between the intuitive and the reflective condition turns out to be significant for SVO scores larger than \( \approx 13.8 \) in our study. In the SVO Slider Measure people with scores between
-12.04 and 22.45 are classified as selfish, while people with scores between 22.45 and 57.15 are classified as prosocial. Accordingly, the range of significant SVO scores covers all individuals with a prosocial SVO score, and also a subset of selfish individuals. To be specific, out of 87 participants who were classified as selfish in our experiment, 24 exhibited SVO scores that belong to the region of significance (27.6%). Taken together, the analysis of responder decisions supports our hypothesis that SVO moderates the effects of adopting an intuitive versus reflective mode of processing on responses to unfair offers.

**Discussion**

We examined whether social value orientation (SVO; Messick & McClintock, 1968; Murphy & Ackermann, 2014; van Lange, 1999) moderates the effects of adopting an intuitive versus reflective mode of processing on responses to unfair ultimatum offers. We assessed SVO one week prior to an ultimatum game experiment in which participants faced a series of ultimatum offers they had to accept or reject. We found that planning to adopt an intuitive versus a reflective mode of processing prior to making these decisions primarily affected prosocial individuals; they were less likely to accept unfair offers when they adopted an intuitive rather than a reflective mode of processing. While this effect also evinced for a subset of selfish individuals, the majority of them was not affected, making similar decisions in both the intuitive and the reflective condition. This pattern of results supports our hypothesis that SVO moderates the effects of intuitive versus reflective modes of processing on responses to unfair offers.

It is interesting that adopting an intuitive versus a reflective mode of processing did not only affect prosocial individuals but also some individuals with rather high SVO scores among those classified as selfish. This result is consistent with research stressing the importance of gradual differences in SVO that can be masked when researchers rely on nominal classifications only (Fiedler et al., 2013; Murphy & Ackermann, 2014). The present research provides additional support for this reasoning.

Previous work has primarily focused on the main effects of adopting an intuitive versus a reflective mode of processing on responses to unfair offers, examining how people decide on average. Although this research has revealed consequences for responses to unfair offers, so far the results did not converge into consistent conclusions regarding the nature of these consequences (e.g., Achtziger et al., 2014; Grimm & Mengel, 2011; Hochman et al., 2015; Knoch et al., 2008; Sutter et al., 2003). We accordingly propose to explore modera-
tors of the effects of intuitive versus reflective modes of processing, and our results suggest SVO as such a moderator. The present research is thus a first step in developing a better understanding of the consequences of intuitive versus reflective modes of processing for responses to unfair offers. Our approach might, however, also be relevant for other domains of social decision making than responding to unfairness in which the effects of intuitive versus reflective modes of processing are unclear (e.g., Rand et al., 2014; Zaki & Mitchell, 2013). For instance, generosity in dictator games, a variant of the ultimatum game in which the responder cannot reject the offer, also yields contradictory findings with regard to effects of adopting an intuitive versus a reflective mode of processing (Achtziger, Alós-Ferrer, & Wagner, 2015; Schulz et al., 2014).

The present research contributes to the current discussion of how SVO affects responder decisions in the ultimatum game. Our results are consistent with one study observing that people with prosocial preferences are less likely to accept unfair offers than those with selfish preferences under varying degrees of cognitive load (Haruno et al., 2014); our data similarly suggest that prosocials are more likely than selfish people to accept unfair offers when adopting an intuitive rather than a reflective mode of processing. However, another study (Karagonlar & Kuhlman, 2013) found that selfish people experience strong feelings of anger when facing an unfair offer and fail to effectively down-regulate this emotional response, resulting in a lower likelihood of accepting the offer compared to prosocials. This finding is hard to reconcile with our data, given that we never observed that selfish people were less likely than prosocials to accept unfair offers, neither when adopting an intuitive nor when adopting a reflective mode of processing. A possible explanation pertains to procedural differences between the studies; the study by Haruno, Kimura, and Frith (2014) and our own study relied on several ultimatum game rounds comprising a range of both unfair and fair offers. Karagonlar and Kuhlman (2013), in contrast, used a one-shot ultimatum game with a single unfair offer (2 out of 10 points). The failure to regulate anger observed among selfish individuals might be particularly prevalent when only a single unfair offer is evaluated, compared to when a range of fair and unfair offers is evaluated over the course of multiple rounds. This is, however, speculative and we feel that future research should address this issue explicitly.

Our findings are also in line with the social heuristics hypothesis (Rand, Greene, & Nowak, 2012; Rand & Kraft-Todd, 2014; Rand et al., 2014), which asserts that intuitive decisions rely on social preferences, whereas reflective decisions foster profit maximization regardless of these preferences. However, prior research on the hypothesis has not taken into account potential differ-
ences in SVO as a possible measure of social preferences. Our results indicate that SVO matters for mode of processing effects in a way that is consistent with the social heuristics hypothesis: differences between prosocial and selfish people evinced in the intuitive condition but not in the reflective condition.
References


Doerflinger, J., Martiny-Huenger, T., & Gollwitzer, P. M. (2015). Planning to deliberate thoroughly: If -then planned deliberation increases the adjustment of decisions to available feedback. Manuscript submitted for publication.


References

115-118. doi: 10.1007/s40881-015-0004-4


References


Luce, R. D. (1986). *Response times: Their role in inferring elementary mental organization*. New York, NY: Oxford University Press.


Mosteller, F., & Tukey, J. (1977). *Data analysis and regression*. Reading:


References


Pfister, R., & Kunde, W. (2013). Dissecting the response in response-


Webb, T. L., Sheeran, P., & Pepper, J. (2012). Gaining control over re-


Eigenabgrenzung


Forschungsartikel I

Mitwirken an den folgenden Aspekten: Präzisierung des theoretischen Rahmens, Interpretation und konzeptionelle Einordnung der Ergebnisse, Erstellung des Manuskripts

Forschungsartikel II

Mitwirken an den folgenden Aspekten: Entwicklung der Idee und Konzeptionalisierung der Studie, Programmierung des experimentellen Paradigmas, Datenerhebung- und Analyse der Daten, Interpretation und konzeptionelle Einordnung der Ergebnisse, Erstellung des Manuskripts

Forschungsartikel III

Mitwirken an den folgenden Aspekten: Entwicklung der Idee und Konzeptionalisierung der Studie, Programmierung des experimentellen Paradigmas, Datenerhebung- und Analyse der Daten, Interpretation und konzeptionelle Einordnung der Ergebnisse, Erstellung des Manuskripts