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ORIGINAL ARTICLE

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 precentral 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.

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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 (e.g., Elsner & Hommel, 2001; Gaschler & Nattkemper, 2012; Herwig, Prinz, & Waszak, 2007; Janczyk, Heinemann, & Pfister, 2012; Janczyk, Nolden, & Jolicoeur, 2014; 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. (e.g., Brass & Haggard, 2008; Gaschler & Nattkemper, 2012; Herwig et al., 2007; Janczyk, Heinemann, et al., 2012; Passingham, Bengtsson, & Lau, 2010; Pfister et al., 2010, 2011).

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.

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 implies 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, Lengfelder, & Gollwitzer, 2011; Lengfelder & Gollwitzer, 2001), and without conscious intent (Bayer, Achtziger, Gollwitzer, & Moskowitz, 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, Dijksterhuis, and Midden (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.

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[1] Note that Berlyne (1957a, b) 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.

[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 stimulus–response links that are provided by forced-choice instructions. We do not deny this possibility and return to this view in the General Discussion. For now, however, as our reasoning was derived from the framework of implementation intentions, we prefer speaking of if–then plans.

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, Steinhauser, & Lehle, 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 input 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, Bayer, and Gollwitzer (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 (Hübner et al., 2010) to data from a flanker task revealed that implementation intentions improve early attentional processes (Bieleke, Dambacher, Hübner, & Gollwitzer, 2013). 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, 1951) that divides task processing into three stages (see Fig. 1a): (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; Miller & Reynolds, 2003; Schweickert, 1978). When using the locus-of-slack 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 Fig. 1b 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

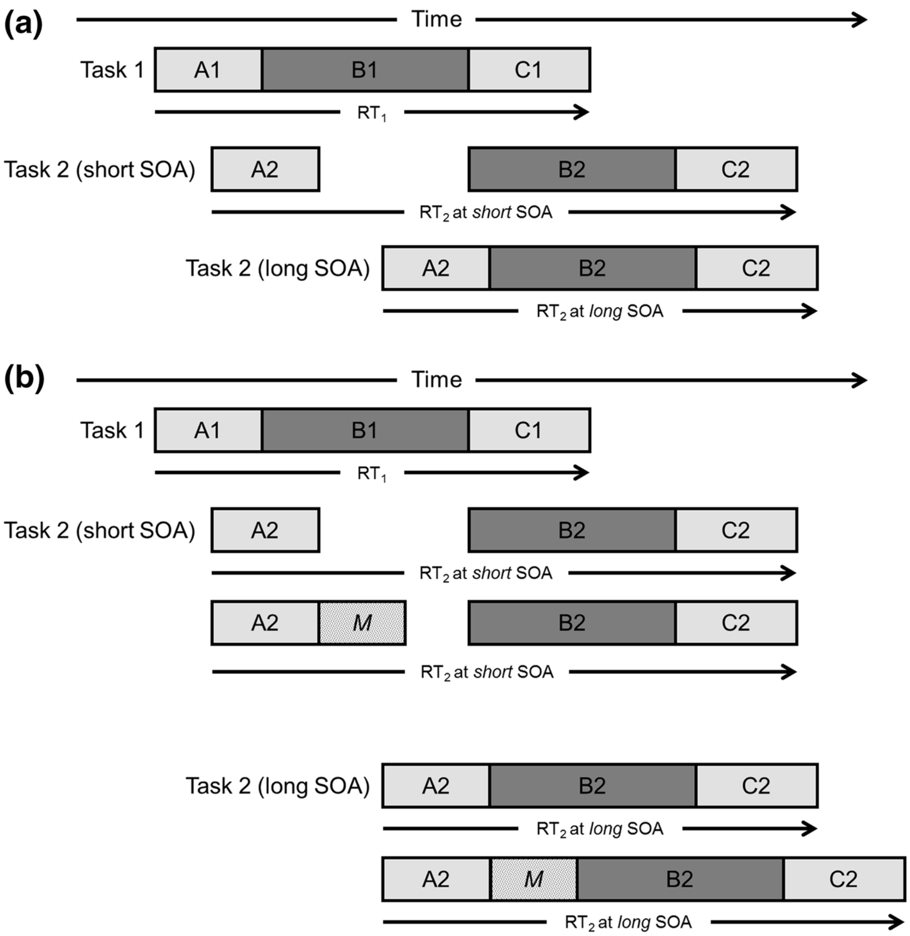

Fig. 1 **a** Illustration of the PRP paradigm. The critical assumption is that the central stage of processing (*B*) represents a processing bottleneck, while perceptual (*A*) and motor (*C*) processes can run in parallel to other stages. At short stimulus onset asynchronies (SOAs), processing of the 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

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 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).[3] Two versions of this experiment were conducted, differing with regard to the levels of SOA (Exp. 1a: two levels; Exp. 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

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[3] In Berlyne's (1957a) experiments both (forced-choice) stimuli were presented in a free-choice trial.

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, 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 1,000 ms. In Experiment 1a, the SOAs were either 50 or 1,000 ms; in Experiment 1b they were 50, 300, or 1,000 ms. In Experiment 1a, each block comprised 60 trials; that is, five repetitions of all combinations resulting from the 2 S1 (X vs. S) ×3 S2 (green vs. red vs. yellow) × 2 SOAs (50 vs. 1,000 ms) design. In Experiment 1b, each block comprised 90 trials because of the additional 300 ms SOA.[4] 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 (Exp. 1a: 50 vs. 1,000 ms, Exp. 1b: 50 vs. 300 vs. 1,000 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. 1,000 ms; 1b: 50 vs. 300 vs. 1,000 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 ε-estimate in these cases.

Results

Experiment 1a

Mean RT2s (2.6 % outliers) are visualized in Fig. 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,

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[4] Due to a programming error, participants 1–16 of Experiment 1b had only 85 instead of 90 trials per block.

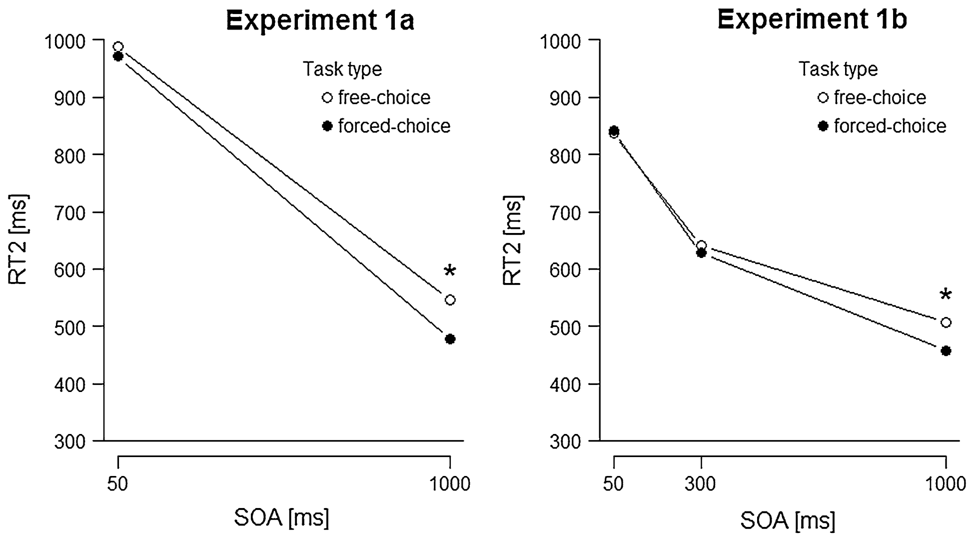

Fig. 2 Mean response times in Task 2 (RT2) as a function of task type and stimulus onset asynchrony (SOA). *Asterisks* mark a pairwise difference at $p \leq 0.05$ (two-tailed)

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)

Task type	Experiment 1a		Experiment 1b		
	SOA (ms)		SOA (ms)		
	50	1,000	50	300	1,000
RT2 (ms)					
Forced-choice	971	477	842	628	458
Free-choice	989	546	838	641	506
PE2					
Forced-choice	5.2	6.0	6.3	6.5	5.5
RT1 (ms)					
Forced-choice	730	623	657	640	659
Free-choice	713	597	645	642	648
PE1					
Forced-choice	4.9	3.8	3.8	3.7	2.7
Free-choice	4.4	4.3	5.0	3.1	1.5

$F(1,11) = 3.02$, $p = 0.110$, $\eta_p^2 = 0.22$. 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 1,000 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 1,000 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: $F(1,11) = 0.19$, $p = 0.671$, $\eta_p^2 = 0.02$. PE1s showed little variation and no effect was significant, SOA: $F(1,11) = 0.34$, $p = 0.573$, $\eta_p^2 = 0.03$, task type: $F(1,11) = 0.01$, $p = 0.944$, $\eta_p^2 < 0.01$, interaction: $F(1,11) = 1.89$, $p = 0.196$, $\eta_p^2 = 0.15$.

Experiment 1b

Mean RT2s (2.9 % outliers) are visualized in Fig. 2 (right panel; see also Table 1) and replicate the pattern from Experiment 1a. Clearly, a PRP effect was evident, $F(2,46) = 183.40$, $p < 0.001$, $\eta_p^2 = 0.89$, $\varepsilon = 0.65$, and responses again tended to be faster in the forced-choice than in the free-choice task, $F(1,23) = 3.25$, $p = 0.085$, $\eta_p^2 = 0.12$. 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, $F(2,46) = 6.68$, $p = 0.003$, $\eta_p^2 = 0.23$. Mean PE2s are summarized in Table 1 and did not differ between SOAs, $F(2,46) = 0.59$, $p = 0.505$, $\eta_p^2 = 0.02$, $\varepsilon = 0.71$. 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 1,000 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 1,000 ms, respectively, $F(2,46) = 0.50$, $p = 0.563$, $\eta_p^2 = 0.02$, $\varepsilon = 0.76$.

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: $F(2,46) = 0.19$,

$p = 0.758$, $\eta_p^2 = 0.01$, $\varepsilon = 0.73$, task type: $F(1,23) = 0.74$, $p = 0.399$, $\eta_p^2 = 0.03$, interaction: $F(2,46) = 0.51$, $p = 0.606$, $\eta_p^2 = 0.02$. Participants made less errors the longer the SOA, $F(2,46) = 7.85$, $p = 0.001$, $\eta_p^2 = 0.25$. No other effect was significant, task type: $F(1,23) = 0.17$, $p = 0.685$, $\eta_p^2 = 0.01$, interaction: $F(2,46) = 2.88$, $p = 0.066$, $\eta_p^2 = 0.11$.

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, Exp. 2 and 3).[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.

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 × 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 → index-finger, middle square → middle-finger, right square → 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 1,000 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) × 6 S2 (3 forced-choice stimuli and 3 free-choice stimuli) × 3 SOAs (50 vs. 300 vs. 1,000 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.

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[5] At least in Experiment 3, Berlyne (1957a) doubled the free-choice trials for analyses to reach a comparable numbers of trials.

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 Fig. 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, $F(2,46) = 446.56$, $p < 0.001$, $\eta_p^2 = 0.95$, $\varepsilon = 0.63$. Overall, responses were faster in the forced-choice than in the free-choice task, giving rise to a significant main effect of task type, $F(1,23) = 12.31$, $p = 0.002$, $\eta_p^2 = 0.35$. 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, $F(2,46) = 4.93$, $p = 0.011$, $\eta_p^2 = 0.18$. Participants committed less errors with an increasing SOA, $F(2,46) = 13.90$, $p < 0.001$, $\eta_p^2 = 0.38$, and they made more errors in the forced-choice task, $F(1,23) = 14.21$, $p = 0.001$, $\eta_p^2 = 0.38$. The interaction was not significant, $F(2,46) = 2.42$, $p = 0.100$, $\eta_p^2 = 0.10$. 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 1,000 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, $F(2,46) = 4.85$, $p = 0.023$, $\eta_p^2 = 0.17$, $\varepsilon = 0.72$. No other effect was significant, task type: $F(1,23) = 0.61$, $p = 0.443$, $\eta_p^2 = 0.03$, interaction: $F(2,46) = 0.05$, $p = 0.953$, $\eta_p^2 < 0.01$. Participants made less errors for longer SOAs, $F(2,46) = 24.39$, $p < 0.001$, $\eta_p^2 = 0.51$, 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, $F(2,46) = 3.41$, $p = 0.042$, $\eta_p^2 = 0.13$.

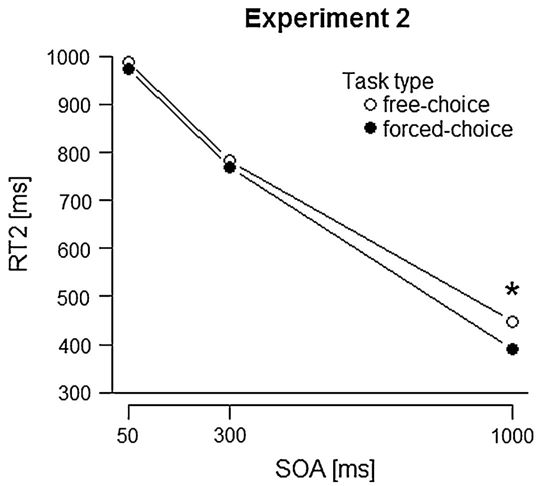

Fig. 3 Task 2 mean response times (RT2) in Experiment 2 as a function of task type and stimulus onset asynchrony (SOA). *Asterisk* marks a pairwise difference at $p \leq 0.05$ (two-tailed)

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

Task type	SOA (ms)		
	50	300	1,000
RT2 (ms)			
Forced-choice	974	769	389
Free-choice	989	783	448
PE2			
Forced-choice	5.2	3.4	1.9
Free-choice	2.6	2.2	0.8
RT1 (ms)			
Forced-choice	778	814	792
Free-choice	784	822	795
PE1			
Forced-choice	5.4	4.3	1.5
Free-choice	4.1	2.3	1.4

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., 2013; Gollwitzer, 1999; 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., 2013; Gollwitzer, 1999; 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, Exp. 2) and the significant interaction revealed a larger brightness effect in forced-choice (1,293 vs. 1,105 ms; difference = 188 ms) than in free-choice trials (1,478 vs. 1,377 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.

Stimuli and apparatus

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 1,000 ms). Then, the stimulus was presented until either R was given or 2,500 ms had elapsed. In case of an error, feedback was displayed (1,000 ms) and the next trial started after 1,000 ms. Each block comprised 72 trials; that is, six repetitions of all combinations resulting from the 2 CSI (500 vs. 1,000 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 2,500 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 Fs ≤ 1.94, all ps ≥ 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 Fig. 4). The ANOVA revealed that RTs were shorter for the bright than for the dark stimuli, $F(1,95) = 33.75$, $p < 0.001$, $\eta_p^2 = 0.26$, but task type had no effect, $F(1,95) = 0.91$, $p = 0.344$, $\eta_p^2 = 0.01$. Importantly, and as expected, the interaction was significant, $F(1,95) = 55.57$, $p < 0.001$, $\eta_p^2 = 0.37$. 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 (Fig. 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, $F(1,77) = 6.97$, $p = 0.010$, $\eta_p^2 = 0.08$, 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 %), $F(1,95) = 35.94$, $p < 0.001$, $\eta_p^2 = 0.27$.

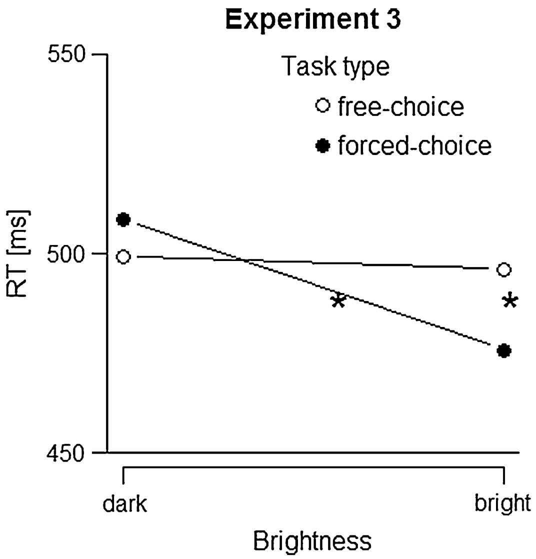

Fig. 4 Mean response times (RT) in Experiment 3 as a function of task type and stimulus brightness. *Asterisks* mark a pairwise difference at $p \leq 0.001$ (two-tailed)

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, Exp. 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 processing (Achtziger et al., 2012; Bieleke et al., 2013; 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 Experiment 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., 2013). 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, Heinemann, et al., 2012; Passingham et al., 2010; Pfister et al., 2010, 2011). 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, Pfister, Crognale, & Kunde, 2012; Janczyk, Skirde, Weigelt, & Kunde, 2009; Kühn, Elsner, Prinz, & Brass, 2009, Exp. 3; 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, Heinemann, et al., 2012). The reasons for the discrepancies are unknown at present and deserve further systematic investigation (see 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., Ratcliff, 1978; Hübner et al., 2010). 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 predefined 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.[6] 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, 2014). 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 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

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[6] This refers not only to the immediately preceding trial, but to the longer history of previous responses.

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., 2013; 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.

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