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Copying Competitors? Interdependency Modulates Stimulus-Based Retrieval of Observed Responses

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We investigated whether stimuli are integrated with responses that are merely observed, but not executed by oneself, and examined the moderating role of mutual dependency between coactors on the binding and retrieval of stimuli and observed responses. A prime-probe paradigm was shared between 2 coactors who took the roles of actor and observer in turns. We also varied the interdependency between the pairs of participants (cooperation vs. competition vs. independence). Results of Experiment 1 indicated that prime observers showed stimulus-based retrieval of observed responses when it was their turn to act in the 2 interdependent conditions, whereas prime observers in the independent condition did not. Results of Experiment 2 excluded the possibility that the stronger retrieval effects in the interdependent conditions are due to social facilitation of retrieval processes in general, as interdependency did not modulate stimulus-based retrieval of self-generated responses. We conclude that binding and retrieval of stimuli and observed responses is a conditionally automatic process that is contingent on mutual dependency between actor and observer.

Keywords: stimulus-response binding, event files, episodic retrieval, observational learning, action corepresentation

According to cognitive accounts of automatic behavior regulation, executing a response in close temporal proximity to a presented stimulus suffices to integrate the mental representation of the stimulus with the activated response code into a transient episodic memory unit (i.e., stimulus-response binding or *event file*, Hommel, 1998). The basic rationale behind the "event file idea" is that as long as the event file is accessible in memory, repeating one of its elements will retrieve the entire file, including the associated response. Re-execution of the same response is therefore facilitated if the stimulus is encountered again (e.g., Denkinger & Koutstaal, 2009; Hommel, 1998, 2004; Horner & Henson, 2009, 2011; Waszak, Hommel, & Allport, 2003, 2005). More recent findings complement this research in showing that such binding and retrieval effects also occur for irrelevant stimuli: That is, responding to a relevant (target) stimulus in the presence of another irrelevant (distractor) stimulus leads to an integration of the distractor into the event file, meaning that the distractor's mental representation also becomes associated with the activated response codes. Subsequent repetition of the distractor reactivates the previous response and primes the response that became associated with the distractor (Rothermund, Wentura, & De Houwer, 2005; see also Frings & Moeller, 2012; Frings & Rothermund, 2011; Frings, Rothermund, & Wentura, 2007; Giesen, Frings, & Rothermund, 2012; Giesen & Rothermund, 2011, 2013a, 2013b; Mayr & Buchner, 2006; Mayr, Buchner, & Dentale, 2009; Moeller, Rothermund, & Frings, 2012; Wiswede, Rothermund, & Frings, 2013). By integrating irrelevant aspects of a situation into an event file, the cognitive system takes advantage of the fact that in our daily lives, certain relevant and irrelevant stimuli frequently co-occur together. In this regard, many initially irrelevant aspects of the situation may become informative and elicit the appropriate behavior as a consequence of implicit learning.

However, not all behavior routines and action knowledge regarding the appropriateness of actions in specific situations are based on personal experience with executing these actions. Most of our action repertoire is acquired by observing the actions of others in specific situations (Bandura, 1986). The present study was motivated by combining accounts of behavior automatization with social learning theory to examine whether stimuli can also become associated with responses that are merely observed, but not executed by oneself. We were interested in whether a subsequent stimulus repetition also triggers retrieval of observed responses (in close analogy to "standard" stimulus-response binding and retrieval effects).

In our view, there is a range of existing studies from related fields of research that encourage our reasoning. First off, response execution appears not to be the only way to activate response codes. For instance, Kühn, Elsner, Prinz, and Brass (2009) demonstrated that the voluntary intention *not* to act (which represents

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an internal response without any observable motor action) can become associated with a subsequent effect tone, reflecting so called nonaction-effect bindings (see also Kühn & Brass, 2010a, b; for related evidence on the binding and retrieval of stimuli and nonactions, see Giesen & Rothermund, 2013b). Together, these findings suggest that sensory consequences can become associated with the decision not to act, and thus do not necessarily hinge on motor code activation. Going one step further, several studies indicate that *observing* an action of another person is sufficient to automatically activate the corresponding motor representations in the observer (for reviews, see Brass & Heyes, 2005; Rizzolatti & Craighero, 2004).[1] For instance, existing evidence in this regard is based on facilitation and interference effects participants exhibit when executing a response while simultaneously observing compatible or incompatible videotaped responses (e.g., Brass, Bekkering, & Prinz, 2001; Brass & Heyes, 2005). In addition, recent studies on so-called action-specific effects could show that perceptual judgments regarding the size, distance, or movement speed of an object are influenced by observing another person performing an action on these objects (e.g., Witt, Sugovic, & Taylor, 2012; Witt, South, & Sugovic, 2014). For example, objects that are unreachable for an observer but are located within reaching space of an actor are not only judged to be spatially closer by the observer after observing how another person uses a tool to reach for that object (Bloesch, Davoli, Roth, Brockmole, & Abrams, 2012), but also elicit motor actions in the observer that are suitable for grasping that object (Costantini, Committeri, & Sinigaglia, 2011). These findings suggest that observers map another person's reaching space onto their own reaching space, thereby establishing shared representations. According to Witt and colleagues (2014), observers will then project their own abilities on the situation and simulate the action as if they were in the other person's position. The idea that observers mentally represent observed actions as if they actually performed the actions themselves is also central for studies on joint action (for overviews, see Creem-Regehr, Gagnon, Geuss, & Stefanucci, 2013; Knoblich & Sebanz, 2006; Sebanz, Bekkering, & Knoblich, 2006). For instance, Sebanz, Knoblich, and Prinz (2003) presented pictures of an index finger pointing to the left or to the right, wearing either a red or green ring. Two participants sitting side-by-side had to categorize the ring's color; each participant was in charge of one response only. Interestingly, although the pointing direction was irrelevant for the task, participants were faster to respond to the stimulus' color if the pointing stimulus referred to "their" action, and slower if the pointing stimulus referred to "the other's" action. Sebanz and colleagues (2003) suggested that this incompatibility effect results from mentally corepresenting the observed actions of a coactor, motivating the term "social" or "joint" Simon effect (Sebanz et al., 2003, 2006; but see Dittrich, Rothe, & Klauer, 2012; Dolk, Hommel, Prinz, & Liepelt, 2013; Dolk et al., 2011, for an alternative interpretation).

However, there is hardly any evidence on whether observed responses—because they are mentally represented like one's own responses—may become the subject of binding mechanisms and hence gain functional value in the automatic regulation of behavior. A recent study by Paulus, Van Dam, Hunnius, Lindemann, and Bekkering (2011), however, provided evidence that observing the actions of an experimenter during a training phase leads to the acquisition of action-effect bindings that affected observers' performance when it was their turn to act in a later test phase. Yet to our knowledge, no existing study investigated the emergence of short-term binding effects between stimuli and observed responses.

Likewise, it remains an unresolved issue under which conditions observers are particularly likely to employ stimulus-based retrieval of observed responses for action regulation. Certainly, people will not blindly copy every act they observe in another person (Bandura, 1986). In order to understand in which situations people will rely on automatic stimulus-based retrieval of observed responses, it is feasible to assume that the relationship between observer and actor plays a crucial role. Although relevant work on this issue is still lacking, recent findings on the related topic of action corepresentation effects seem to support this reasoning: Several studies, indeed, document that the relationship between two coactors' affects the way participants mentally represent observed actions. Interestingly, previous research findings highlighted different aspects of the relationship as being most influential in bringing about the effects. Some studies suggest that interference effects in the joint Simon task are stronger in positive/cooperative interactions between coactors compared to negative/competitive encounters (e.g., Hommel, Colzato, & van den Wildenberg, 2009; Iani, Anelli, Nicoletti, Arcuri, & Rubichi, 2011; Kuhbandner, Pekrun & Maier, 2010). In turn, Ruys and Aarts (2010) hold the view that action corepresentation is particularly likely whenever participants' goal attainment depends on the action of their coactor. Accordingly, they provided evidence for action corepresentation effects in cooperative *and* competitive (i.e., in interdependent) contexts compared to an independent context (for a related finding, see also Müller et al., 2011).

So far, existing evidence indicates that people mentally represent actions they merely observed just like the actions they performed by themselves; further on, this process is enhanced or particularly likely to occur if the observed actions were performed by persons whose behavior affects the goals of the observer. The present study sought to investigate the functional value of this apparent "mental prioritization" (cf. Shteynberg, 2010) of responses observed in relevant others beyond cognitive corepresentation. That is, we examined whether people also employ observed responses from relevant others for action regulation. In particular, the present experiments had two aims. First, we were interested in whether merely observing a response in close temporal proximity to a stimulus leads to a stimulus-response binding. In this case, repeating the stimulus on a later occasion should lead to a retrieval of the observed response and should exert an influence on the behavior of the former observer when it is his or her turn to respond. Second, we wanted to know whether binding and retrieval of stimuli and observed responses is modulated by interdependency between actor and observer. We tested two independent hypotheses on this issue. First, we wanted to know whether any form of interdependency increases the likelihood of retrieving event files linking a stimulus with an observed action, compared to an independent condition (Ruys & Aarts, 2010). Second, we were

[1] Note that although "nonactions" and observed actions are both characterized by an absence of any self-generated motor action, there is still a qualitative difference between nonactions and observed actions: In contrast to the former, the latter were not initially intended or decided upon by oneself.

interested in whether cooperative interactions produce stronger retrieval effects of these episodes compared to competitive interactions (Hommel et al., 2009; Iani et al., 2011; Kuhbandner et al., 2010).

We approached these questions with a modified version of a sequential priming paradigm (Rothermund et al., 2005) in which a color categorization task was shared between two participants. Word stimuli were presented to each participant in a sequence of two displays (called *prime* and *probe*). For one participant (the actor), the prime word was presented in red or green; for the other participant (the observer), the same prime word was presented in white font only. As a consequence, prime observers effectively saw *no target features* (red/green font color in this case) during the prime. Thus, although the observer could easily observe the actor's response, she or he could neither execute nor simulate the prime task, nor could she or he form an association between a target feature and the observed response (i.e., a stimulus-stimulus binding). Crucially, in the subsequent probe display, the former prime observer became the probe actor and now saw a colored probe word and had to categorize its color. We manipulated compatibility between the to-be-observed prime responses and to-be-executed probe responses. Furthermore, word identity was either repeated from prime to probe (word repetition) or not (baseline). Stimulus integration with observed responses in the prime and retrieval of this stimulus-response binding in the probe is indicated by an interaction of stimulus relation and response compatibility in the probe.

To examine the moderating influence of interdependency on binding and retrieval of stimuli with observed responses, each pair of participants was randomly assigned to one of three groups. Both participants either had to cooperate (positive interdependency), compete against each other (negative interdependency), or work on their own (independence condition) to receive an extra reward (cf. Iani et al., 2011; Ruys & Aarts, 2010). If the employment of stimulus bindings with observed responses for behavior regulation is a function of interdependency (global interdependency hypothesis; cf. Ruys & Aarts, 2010), stronger stimulus-based retrieval of observed responses should occur in the positive and negative interdependency conditions compared to the independent condition. Furthermore, according to the positive interdependency hypothesis, these effects should be stronger for cooperative situations compared to the competitive interaction condition (e.g., Hommel et al., 2009; Iani et al., 2011).

Experiment 1

Method

Participants. A sample of 119 students of the University of Jena was recruited for the experiment. Thirteen participants had to be excluded because they either did not adhere to instructions ($n = 2$), did not believe the group manipulation ($n = 2$), and/or worked inattentively and thus were extreme outliers in terms of error rates (more than three interquartile ranges above the third quartile of the sample distribution of error rates, Tukey, 1977; $n = 8$). Thus, data of 106 (72 female) participants with a mean age of 22.7 years ($SD = 3.9$) were analyzed. Participants were randomly assigned and worked in pairs either under positive ($n = 33$) or negative ($n = 36$) interdependency, or independently ($n = 37$) of each other.[2] All participants reported not to be acquainted with their coactor. Experimental sessions lasted 35–40 min; participants were compensated with partial course credit for their participation and received sweets/drinks or additional partial course credit as an extra reward if they performed well in terms of speed (i.e., more than 75% responses faster than 750 ms) and accuracy (i.e., less than 15% errors) and with respect to their assigned interdependency condition (details follow).

Experimental set-up and stimuli. Two participants were seated opposite to each other at a table, each one in front of a 19-in. flat-screen monitor that prevented direct eye contact between participants. Within reach of each participant's left and right hand, two response pads—one with a red and one with a green push-button in the middle and two black rest-state keys in front of and behind each push-button (see Figure 1)—were fastened to the table. The response pads were connected to the computer via the parallel port and collected participants' color categorization responses (i.e., release responses of rest-state keys, hit responses of red/green push-buttons). The experiment was programmed with E-Prime 2.0. Twenty-five neutral, frequently used German adjectives that were either mono- or disyllabic and consisted of four to seven letters (e.g., small, quiet, edgy) served as stimuli in the experiment. Stimuli were presented centrally in Times New Roman 16-pt font on each participant's monitor on a black blank screen.

Design. The experimental design comprised a $2 \times 2 \times 3$ mixed-factors design with the within-subject factors stimulus relation and response compatibility and the between-subjects factor interdependency. Stimulus relation was manipulated by presenting the same prime word in the probe in 50% of all prime-probe sequences (word repetition, e.g., small—small) and by presenting two different words in prime and probe in 50% of all prime and probe sequences (baseline, e.g., quiet—small). Response compatibility was varied by requiring probe responses that were compatible to observed prime responses in 50% of all prime-probe sequences (response compatible, e.g., red—red), and by requiring probe responses that were incompatible to observed prime responses in 50% of all prime-probe sequences (response incompatible, e.g., green—red). Interdependency was manipulated by randomly assigning each pair of participants to one of three groups: (a) pairs in the "positive interdependency" condition had to cooperate and perform well as a team in order to gain an extra reward (i.e., either both participants or none received a reward), (b) pairs in the "negative interdependency" condition had to compete against each other because only one participant (the better one) but not the other of each pair would gain the extra reward, (c) pairs in the "independence" condition worked independently of each other to gain an extra reward (i.e., either none, one, or both participants were rewarded). Release reaction time (RT) of the rest-state keys served as the primary dependent variable (we also collected hit RT for pressing the push-buttons but refrained from analyzing them, as they are confounded with movement speed).

[2] Ten participants in Experiment 1 and 10 participants in Experiment 2 in the "independence" condition worked with a confederate because no partner could be recruited; however, data of confederates were excluded from all analyses.

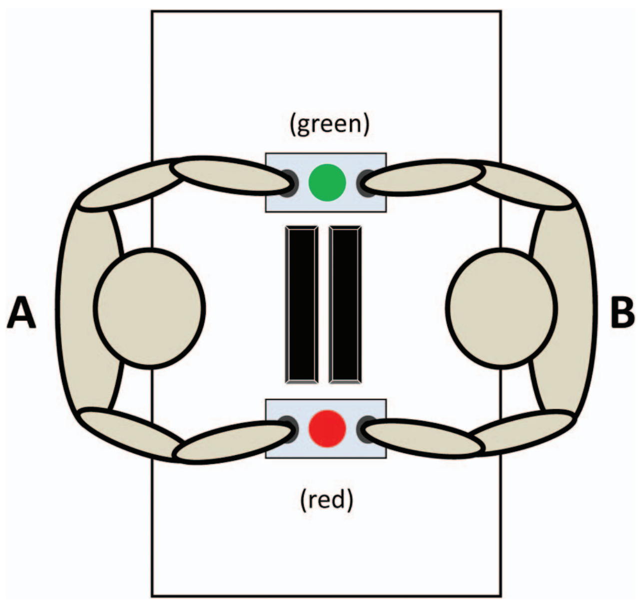

Figure 1. Schematic overview of the experimental setup for Participants A and B. See the online article for the color version of this figure.

Procedure. During the experiment, two participants (referred to as Participants A and B) worked pairwise at a time. Instructions for both participants were presented on each participant's screen. For both prime and probe displays, participants' task was to categorize the color of the presented word stimulus by pressing the corresponding (i.e., red/green) push-button in the middle of the response pads. The identity of the word was irrelevant for the task and served as a distractor (Rothermund et al., 2005) in both prime and probe displays. Importantly, the color categorization task was shared between both participants. Only one participant of each pair saw a colored word during the prime or probe display (the actor); for the other participant (the observer), the word was presented in white (see Figure 2a). That is, for the first 160 prime-probe sequences, Participant A was the "prime actor" and had to categorize only the color of prime stimuli, whereas Participant B was the "probe actor" and had to categorize only the color of probe stimuli. By implication, Participant B was the prime observer, and Participant A was the probe observer. Participants switched roles after 160 prime-probe sequences. Because release RT of the rest-state keys served as the dependent variable of interest, participants were instructed to hold down the rest-state keys at all times during the experiment and to release them only to press the red or green push-button if it was their turn to respond.

After reading the instructions, participants performed a practice block of 32 prime-probe sequences that included feedback for erroneous or too slow responses. That is, if the prime or probe actor performed an erroneous (release and/or hit) response, the message "Error—wrong key!" appeared; if release responses were slower than 750 ms, the message "Respond faster!" appeared; if the wrong person (i.e., the prime or probe observer) released a rest-state key, the message "Error—wrong person!" appeared. All feedback messages were presented centrally in white font on red background to both participants for 1,000 ms. Upon successful completion of the practice block, participants were informed of the respective rules of how to gain the extra reward, depending on which interdependency condition they were assigned to.

Each pair of participants then performed two blocks of 160 prime-probe sequences that were constructed with respect to the factorial design. For each sequence, a prime word was randomly chosen from the stimulus set. In case of word repetitions, the prime word was also presented as probe word; in case of the baseline condition, a different word was sampled as probe word. Identical stimuli were never sampled for two successive prime-probe sequences. Actors and observers in prime and probe displays always saw the same words, however, in different font colors. Prime stimulus color was counterbalanced, meaning that 50% of all prime stimuli were presented in red, and 50% were presented in green to the prime actor (probe stimulus color depended on the experimental factor response compatibility, implying that 50% of all probe stimuli were presented in red and 50% were presented in green to the probe actor).

Each prime-probe sequence was as follows (see Figure 2a): First, as a ready signal, three exclamation marks (!!!) were presented centrally on each participant's screen in white font for 500 ms, followed by a brief fixation cross presented for 250 ms. Subsequently, the prime display appeared in which a word stimulus was presented; for the prime actor, the word was presented in either red or green font, and for the prime observer, the word was shown in white. Stimuli remained on screen until prime actors hit one of the push-buttons or until a maximal duration of 1,500 ms had elapsed. As soon as prime actors resumed to press both rest-state keys, another fixation cross was presented for a variable duration (between 150 and 350 ms, $M = 250$ ms) to prevent an exact anticipation of the probe display onset. Then the probe display appeared in which another word stimulus was presented: For the probe actor, the word was presented in red or green font, and for the probe observer, the word was shown in white. Stimuli remained on screen until probe actors hit one of the push-buttons or until a maximal duration of 1,500 ms had elapsed. The sequence would only continue if probe actors resumed pressing both rest-state keys. Because we were interested in whether participants would acquire and retrieve bindings between a stimulus and observed responses during the prime, we added a memory test for prime observers to guarantee that they attended to the responses of prime actors. Therefore, after a sample of 25% randomly selected probe displays, a memory test was presented only to the prime observer/probe actor, who was asked to press the push-button that was pressed by the prime actor in the preceding prime display. The memory test remained on screen until the prime observer hit one of the push-buttons. During the memory test for prime observers, the prime actor/probe observer's screen remained black. Once prime observers resumed pressing both rest-state keys, the sequence ended with an intertrial interval of 1,250 ms, during which participants were reminded to keep all rest-state keys pressed to continue. After every 40 prime-probe sequences, participants received feedback on their past performance (amount of errors and slow responses). To reinforce the interdependency manipulation, participants in the positive and negative interdependency conditions were also informed about their partner's performance in addition to their own performance, together with the information, "Remember: You work together/against each other," respectively. Feedback was presented for 10 s.

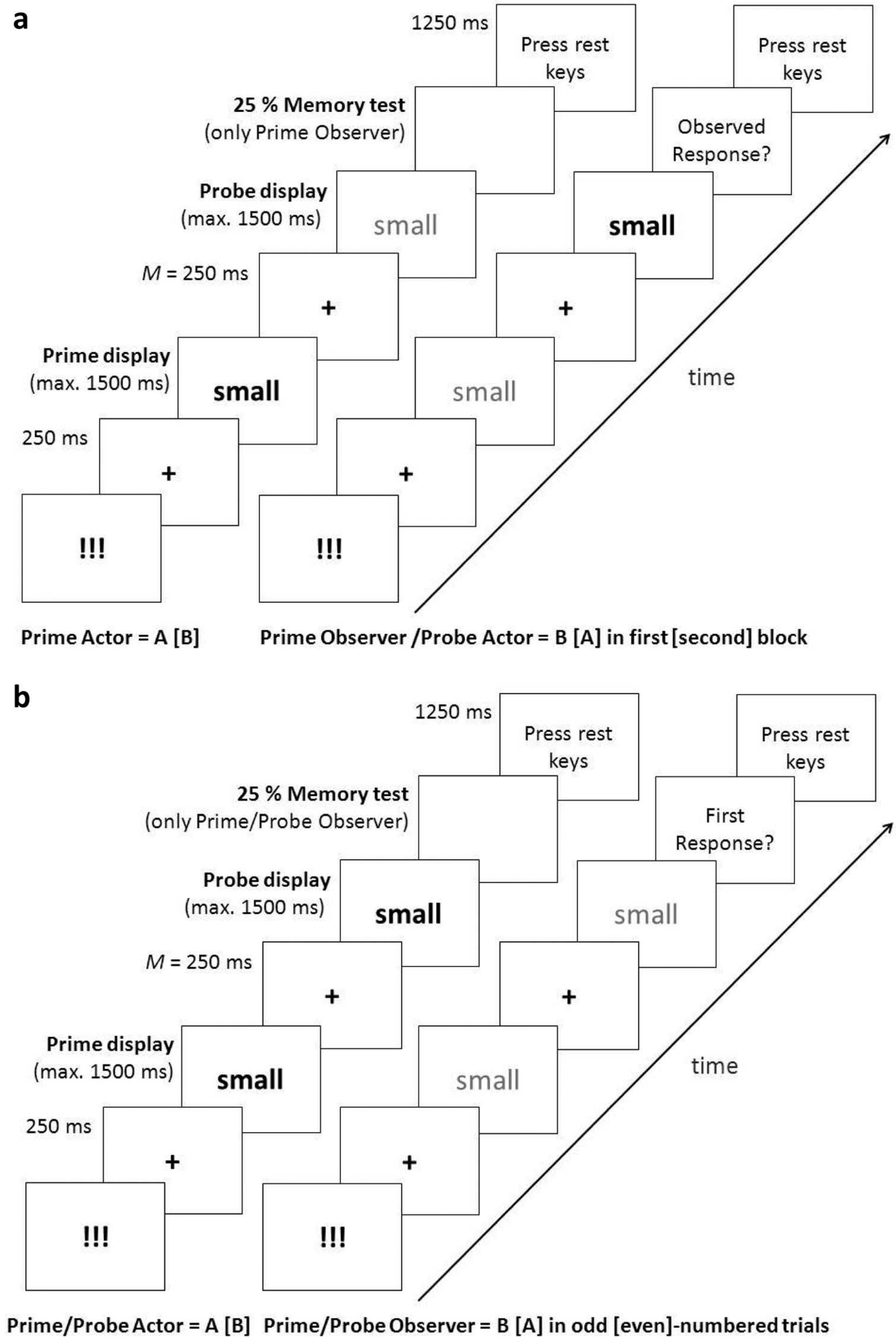

Figure 2. Schematic prime-probe sequence from each participant's perspective. (a) In Experiment 1, Participant A started as the prime actor and Participant B as the prime observer/probe actor. After the first block, Participants A and B switched roles. (b) In Experiment 2, Participant A started as prime/probe actor and Participant B as prime/probe observer. Participants switched roles after each prime-probe sequence. In both experiments, word stimuli were presented in red/green font (depicted in black boldface) to actors; to observers, word stimuli were presented in white font (depicted in gray). Stimuli are not drawn to scale.

At the end of the experiment, participants received a brief paper questionnaire as a manipulation check. Using 7-point bipolar scales, they were asked to rate the experimental situation as 1 (*cooperative*) versus 7 (*competitive*); three additional items were used to assess participants' experienced comfort versus discomfort during the experiment (i.e., 1 = *easy/pleasant/positive* vs. 7 = *difficult/unpleasant/negative*; Cronbach's alpha = .71). Participants were further asked to rate how agreeable or disagreeable they perceived their coactor with four additional items (i.e., 1 = *agreeable/confident/friendly/competent* vs. 7 = *disagreeable/insecure/unfriendly/incompetent*; Cronbach's alpha = .87). Participants were also asked whether they were acquainted with their coactor, and whether they had used any strategies during the task. After completion of the questionnaire, participants were thanked, debriefed, and rewarded (extra rewards were distributed according to the rules of the respective interdependency condition participants were assigned to).

Results

Manipulation check. We computed mean ratings of the experimental situation and participants' perception of their coactors for each interdependency condition (see Table 1), which were then entered into separate 3 (group: Independence vs. Negative Interdependency vs. Positive Interdependency) one-way analyses of variance (ANOVAs). Results indicated that interdependency conditions differed significantly only with respect to the cooperation/competition dimension, $F(2, 103) = 22.06$, $p < .001$, $\eta_p^2 = .30$. Post hoc t tests with Bonferroni adjustment showed that participants in the negative interdependency condition judged the situation as more competitive ($M = 5.1$, $SD = 1.3$) than the participants in the positive interdependency ($M = 3.1$, $SD = 1.7$), $t(67) = 5.49$, $p < .001$, or independence conditions ($M = 3.2$, $SD = 1.3$), $t(71) = 6.28$, $p < .001$. Ratings did not differ between the positive interdependency and independence conditions, $|t| < 1$. Furthermore, interdependency conditions did not differ with respect to ratings of perceived (dis)comfort and perceived (dis)agreeableness of the coactor (i.e., both analyses missed conventional levels of significance, $F[2, 103] = 2.57$, $p = .08$, and $F[2, 103] = 1.28$, $p = .28$, respectively). These findings confirm that our interdependency manipulation selectively affected perceived cooperation/competition among pairs of participants, but did not affect other influential factors like participant's mood (cf. Kuhbandner et al., 2010) or personal appreciation of their coactor (cf. Hommel et al., 2009).

Prime observers' memory for observed responses. To exclude the possibility that prime observers in the interdependency conditions differed with respect to their motivation to observe and memorize prime actors' responses, we calculated mean error rates in the memory test for prime observers separately for each interdependency condition (see Table 1). A 3 (group: Independence vs. Negative Interdependency vs. Positive Interdependency) one-way ANOVA on mean error rates showed that prime observers' memory test performance did not differ between the interdependency conditions, $F < 1$. We conclude that prime observers across all interdependency conditions attended to and consequently encoded observed prime responses.

Probe performance. Only probe actors' release RTs were analyzed. Prime-probe sequences with erroneous responses of the prime and/or probe actor (1.8%), erroneous responses in the memory test for observed prime responses (0.6%), and probe release RT outlier values[3] (0.5%) were excluded from analyses. Because probe actors made only few errors in the color categorization task, error data were not further analyzed. We computed probe actors' average release RT for every condition of the factorial design and separately for each participant (see Table 2). These means were then entered into a 2 (stimulus relation: Word Repetition vs. Baseline) × 2 (response compatibility: Compatible vs. Incompatible) × 3 (group: Independence vs. Negative Interdependency vs. Positive Interdependency) mixed-models multivariate analysis of variance (MANOVA).

Results revealed significant main effects of stimulus relation, $F(1, 103) = 9.73$, $p = .002$, $\eta_p^2 = .09$, response compatibility, $F(1, 103) = 15.01$, $p < .001$, $\eta_p^2 = .13$, and interdependency, $F(2, 103) = 3.35$, $p = .04$, $\eta_p^2 = .06$, indicating that probe actors responded faster in sequences with word repetitions (479 ms) compared to baseline sequences (483 ms). They responded faster in sequences in which their probe response was compatible (476 ms) rather than incompatible (485 ms) to the observed prime response. Additionally, probe actors were faster in the negative interdependency (472 ms) and independence conditions (468 ms) compared to probe actors in the positive interdependency condition (502 ms), respectively. These main effects were further qualified by two interactions. First, the Stimulus Relation × Response Compatibility interaction was significant, $F(1, 103) = 14.17$, $p < .001$, $\eta_p^2 = .12$. Repetition of the prime word (compared to baseline) in the probe produced a significant RT benefit of $\Delta = 9$ ms, $t(105) = 4.53$, $p < .001$, if probe actors had to execute responses that were compatible to observed prime responses, whereas word repetition led to a nonsignificant RT cost of $\Delta = -2$ ms, $|t| < 1$, if probe actors had to execute a response that was incompatible to the observed prime response. Thus, although probe actors only observed responses during the prime, their performance pattern in probe trials mimics classical stimulus-response binding and retrieval effects (Rothermund et al., 2005). This indicates that stimuli were bound with observed responses during the prime and later retrieved them in the probe. Second, and most central to our prediction, the three-way interaction of stimulus relation, response compatibility, and interdependency was also significant, $F(2, 103) = 3.19$, $p = .04$, $\eta_p^2 = .06$, indicating that retrieval effects for bindings between observed prime responses and word stimuli (i.e., the Stimulus Relation × Response Compatibility interaction) differed between the interdependency conditions (see Figure 3a). Planned contrasts corresponding to the two independent hypotheses that were tested in our study[4] (global and positive interdependency hypotheses, respectively) revealed that the Stimulus Relation × Response Compatibility interaction was stronger for the two interdependent conditions ($S \times R_{negative} = 9$ ms, $SD = 30$ ms; $S \times R_{positive} = 21$ ms, $SD = 38$ ms; see Table 2 for computation of interaction terms) than for the independence condition (S ×

[3] Probe release RTs below 250 ms or more than three interquartile ranges above the third quartile of the individual distribution of probe release RTs were regarded as outliers (Tukey, 1977).

[4] Each of the two interdependency hypotheses makes a directional prediction. We thus evaluated theses hypotheses with one-tailed tests in order to enhance the power of the tests and to avoid a biased inflation of type II error probabilities (e.g., Maxwell & Delaney, 1990).

Table 1
Means (SD) of Participants' Ratings of the Experimental Situation and Memory Test Performance in Experiments 1 and 2

	Interdependency		
	Independence	Negative	Positive
Experiment 1	$n = 37$	$n = 36$	$n = 33$
Situation perceived as			
Cooperative (1) vs. competitive (7)	3.2_a (1.3)	5.1_b (1.3)	3.1_a (1.7)
Comfortable (1) vs. uncomfortable (7)	3.1_a (1.0)	3.6_b (1.3)	3.4_{ab} (0.8)
Coactor perceived as			
Agreeable (1) vs. disagreeable (7)	2.2_a (1.0)	2.4_a (1.0)	2.6_a (1.3)
Memory test performance (% errors)	2.0_a (3.4)	2.2_a (2.7)	2.4_a (2.9)
Experiment 2	$n = 30$	$n = 30$	$n = 34$
Situation perceived as			
Cooperative (1) vs. competitive (7)	3.7_a (1.7)	4.9_b (1.9)	2.8_c (1.4)
Comfortable (1) vs. uncomfortable (7)	3.0_a (0.9)	3.3_a (1.3)	3.3_a (1.2)
Coactor perceived as			
Agreeable (1) vs. disagreeable (7)	2.4_a (0.7)	2.3_a (1.0)	2.5_a (1.2)
Memory test performance (% errors)			
For observed prime responses	4.2_a (8.4)	11.3_a (16.1)	9.8_a (16.0)
For observed probe responses	4.2_a (11.6)	11.8_a (19.1)	11.4_a (17.8)

Note. Means in the same row with different subscripts differ at $p < .05$.

$R_{independence}$ = 3 ms, SD = 24 ms), $t(103) = 1.87$, $p = .03$ (one-tailed); moreover, the Stimulus Relation × Response Compatibility interaction was also stronger for positive compared to negative interdependency, $t(103) = 1.75$, $p = .04$ (one-tailed). We also tested interaction terms for each interdependency condition against zero, which yielded significant results for both the positive and negative interdependency conditions ($S \times R_{positive}$: $t(32) = 3.28$, $p = .002$; $S \times R_{negative}$: $t(35) = 1.75$, $p = .04$, one-tailed), but not for the independent condition ($S \times R_{independence}$: $|t| < 1$). All other effects failed to reach conventional levels of significance (all Fs < 1.13, all ps > .32).

Discussion

Effects of stimulus-response binding and retrieval were investigated in a shared sequential priming design that allowed us to analyze effects of observed responses in the prime on self-performed actions in the probe. The obtained results are striking in several respects: First, if word stimuli repeated from prime to probe, participants showed a performance advantage if observed prime and to-be-executed probe responses were compatible, whereas a performance disadvantage occurred if observed prime and to-be-executed probe responses were incompatible. Importantly, the word stimuli were presented without the task-relevant feature to the observers, so that it was impossible for observers to prepare, simulate, or execute responses on their own, nor could they form associations between the target features and the observed responses (stimulus-stimulus bindings). The only possibility to link stimuli and responses thus consisted in binding the irrelevant word to the response that was performed by the other participant. We therefore conclude that the obtained pattern of results emerged because for probe actors, word stimuli became associated with the responses they observed during the prime; word repetition in the probe then retrieved the observed responses from memory. Second, as predicted, interdependency between the two participants sharing an experimental session modulated retrieval of observed responses: Whereas stimulus-based retrieval of observed responses was absent for participants who worked independently of each other, it was evident in cooperative and competitive conditions. On the one hand, this finding is consistent with Ruys and Aarts' (2010) proposal and shows that people will employ stimulus-based retrieval of observed responses if their goal attainment depends on the performance of another person. On the other hand, the fact that the retrieval effect more than doubled in size in cooperative compared to competitive pairs of participants also supports the conclusion that bindings between stimuli and observed responses become more readily employed as the relation between coactors gets more positive (cf. Hommel et al., 2009; Iani et al., 2011).

There is, however, a possible objection against this interpretation of our findings. Rather than reflecting a specific effect of interdependence relations on the retrieval of socially observed stimulus–response associations, interdependence might have influenced binding and retrieval processes in general. That is, we cannot exclude that the different social situations that we created in our study affected all kinds of stimulus-based retrieval processes.[5] For example, social contexts can differ in the degree to which they elicit "social facilitation" or "audience effects" (e.g., Zajonc, 1965; see also Guérin, 1993). According to Zajonc (1965), the presence of others facilitates the execution of what he calls "dominant" responses—responses that are either "very well learned or under a strong influence of the stimulus" (p. 272)—a description that might also apply to stimulus-based retrieval effects even when they do not refer to the observed responses of others. Furthermore, effects of social facilitation are more likely to occur if the spectator takes an active interest in the performance of an actor, as opposed

[5] We thank Arnd Florack for directing our attention to this alternative explanation.

Table 2
Means (SD) of Probe Actors' Release RT (ms) in Experiments 1 and 2

Interdependency	Response compatibility (R)	Stimulus relation (S) SR	B	SR-effect (= B − SR)	S × R interaction effect [= $(B - SR)_C - (B - SR)_{IC}$]
Experiment 1					
Independence (n = 37)	C	459 (50)	465 (57)	6 [2.8]	3 [3.9]
	IC	472 (57)	475 (60)	3 [2.8]	
Negative (n = 36)	C	466 (53)	474 (52)	8 [3.4]	9 [5.0]
	IC	475 (61)	474 (54)	–1 [3.0]	
Positive (n = 33)	C	490 (58)	504 (75)	14 [4.5]	21 [6.6]
	IC	510 (73)	503 (66)	–7 [3.7]	
Experiment 2					
Independence (n = 30)	C	381 (35)	388 (41)	7 [2.6]	10 [4.3]
	IC	421 (51)	418 (36)	–3 [2.5]	
Negative (n = 30)	C	394 (51)	395 (53)	1 [1.9]	2 [2.8]
	IC	428 (56)	427 (58)	–1 [2.6]	
Positive (n = 34)	C	402 (58)	407 (63)	5 [2.1]	5 [3.1]
	IC	434 (56)	434 (55)	0 [2.0]	

Note. SR = stimulus repetition; B = baseline; SR-effect = stimulus repetition effect, computed as the difference between B minus SR; S × R Interaction Effect = interaction effect between stimulus relation and response compatibility, computed as the difference between SR-Effects for compatible responses minus SR-Effects for incompatible responses; C = compatible; IC = incompatible. Standard errors of the means in squared brackets.

to an observer who is merely present, but uninterested (Cottrell, Wack, Sekerak, & Rittle, 1968). Because participants in both interdependent conditions depended on their coactors' performance, it is likely that they took a more active interest in their coactors' performance than those in the independent condition. Consequently, retrieval processes in general might have been facilitated in the interdependent conditions due to social facilitation, which offers an alternative explanation for the obtained three-way interaction of Experiment 1. To address this point, we conducted another experiment.

Experiment 2

If differences in the interdependence between pairs of participants affect stimulus-triggered retrieval effects in general, this influence should prevail not only for the retrieval of observed responses, but also for the retrieval of self-performed prime responses. The rationale of Experiment 2 was therefore as follows. Again, pairs of two participants took part in the experiment, but now the prime-probe sequence was no longer shared between participants. Instead, one participant responded in prime *and* probe displays, while the other participant observed the coactor's performance during prime *and* probe display. Participants switched roles after each prime-probe sequence. Each pair of participants was randomly assigned to one of the three interdependency conditions that were identical to the previous experiment. This allowed us to investigate whether the three interdependence conditions affected stimulus-based retrieval of one's *own* prime response in the probe in a similar way as they had influenced the retrieval of observed other's responses in the previous study. If the difference in retrieval effects obtained in Experiment 1 is due to global differences in social facilitation, then the three-way interaction should replicate, and stimulus-based retrieval effects of individually executed prime responses should also be stronger in the interdependent conditions compared to the independent condition.

It is important to note that the focus in Experiment 2 is on bindings between a stimulus and a self-performed response. Except for the explanation focusing on differences in social facilitation, there is no reason to assume that stimulus-based retrieval of one's own prime response should be modulated by the interdependency between coactors. Assuming that interdependence relations do not affect retrieval processes in general but only have a moderating effect on the retrieval of socially observed responses, these simple binding principles should thus operate irrespective of the interdependency factor (i.e., the three-way interaction should be absent).

Method

Participants. Ninety-six students of the University of Jena were recruited for the experiment. Two participants were not allowed to participate in the experiment proper because they did not adhere to instructions and produced too many errors during the practice block. Thus, data of 94 (60 female) participants with a mean age of 23.2 years (SD = 4.2) were analyzed. Participants again worked in pairs either under positive (n = 34) or negative (n = 30) interdependency, or independently (n = 30) of each other (see also Footnote 2). All participants reported not to be acquainted with their coactor. Participants received €3 for their participation and could gain a bar of chocolate as extra reward. Experiment duration and criteria for allocation of extra rewards per interdependency condition paralleled Experiment 1.

Setup, design, materials, and procedure. Experimental setup, design, materials, and procedure were similar to Experiment 1 except for the following changes: The prime-probe sequence was no longer shared between both participants of a pair. Instead, one participant (the actor) responded in both prime *and* probe displays, while the other one (the observer) merely observed the actor's performance during the prime *and* probe. In the next trial, participants switched roles. That is, Participant A was actor in prime and probe on every odd-numbered trial whereas Participant B was observer in those prime and probe trials. In turn, Participant B was actor in prime and probe on every even-numbered trial and Participant A was observer in those prime and probe trials (see Figure

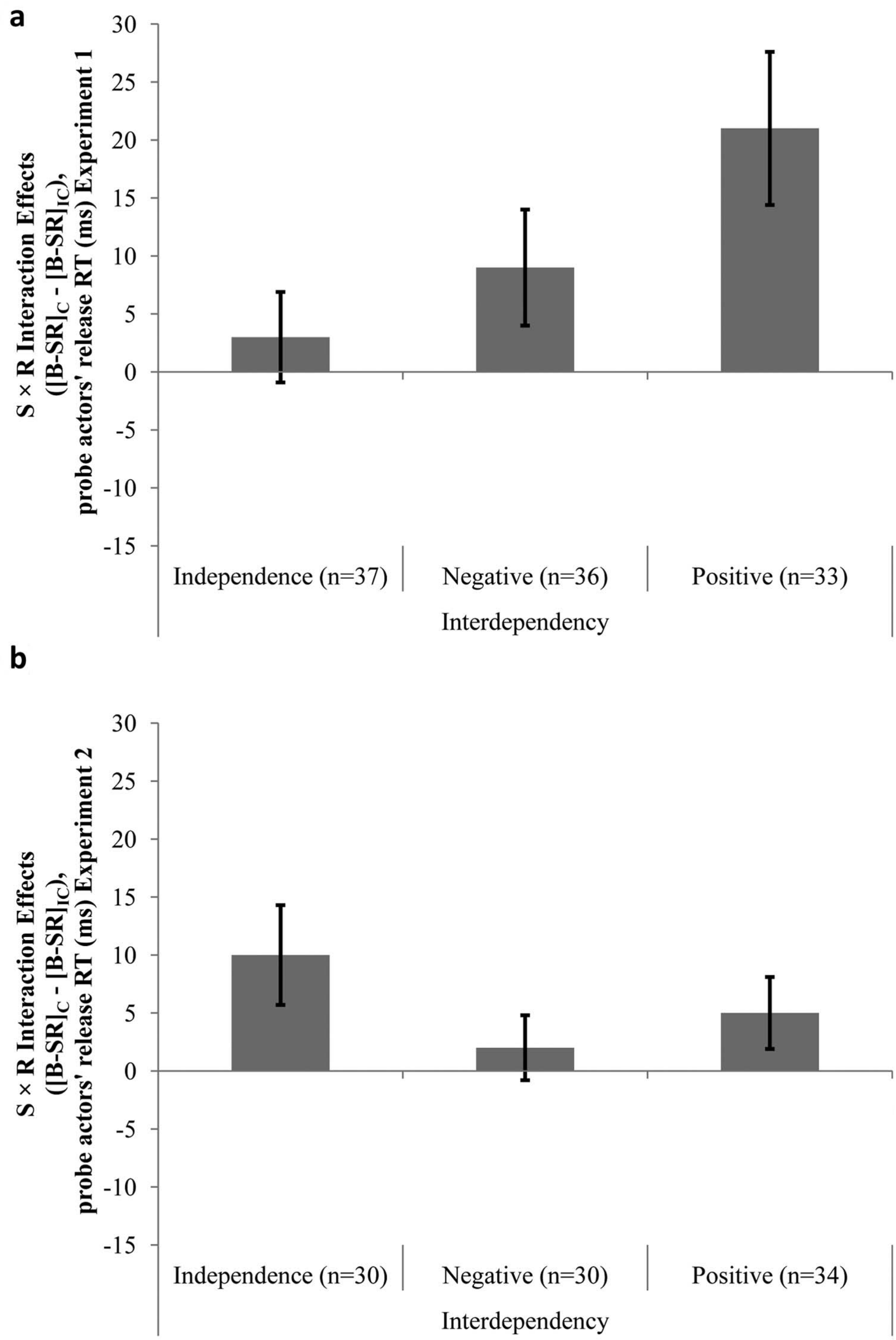

Figure 3. Stimulus Relation × Response Compatibility interaction effects ($[B - SR]_C - [B - SR]_{IC}$) for probe actors' release RT (in ms) as a function of interdependency (a) in Experiment 1 and (b) in Experiment 2. Error bars depict standard errors of the mean. Positive values indicate interaction effects that conform with expected effects due to stimulus-based retrieval of (observed) responses (i.e., positive SR-Effects for probe trials with compatible responses and negative SR-Effects for probe trials with incompatible responses). S = stimulus relation; R = response compatibility; B = baseline; SR = stimulus repetition.

2b). Because each participant either responded in both or neither of the prime and probe displays, the meaning of the response compatibility factor changed slightly compared to Experiment 1: That is, in 50% of all sequences, actors performed the same response in prime and probe (response compatible, e.g., red—red), whereas in the remaining 50% of all sequences, actors performed different responses in prime and probe (response incompatible, e.g., red—green).

Like in Experiment 1, participants again performed a practice block first; upon successful completion of those training trials, they were informed about how they could obtain the extra reward depending on the particular interdependency condition they were assigned to. Each pair of participants then performed 320 prime-probe sequences that corresponded to the experimental design and were subject to the same constraints as in Experiment 1. Because participants switched roles trial-wise, the block structure of Experiment 1 was eliminated in Experiment 2; nevertheless, each participant was actor in 160 prime-probe sequences and observer in the remaining 160 prime-probe sequences. To keep procedures as comparable as possible between both experiments, after 25% of all probe displays, a memory test was presented to observers. In half of all memory test trials, observers were asked for the actor's first (i.e., the prime) response; in the remaining half of all memory trials, observers were asked for the actor's second (i.e., the probe) response. Further procedural details (e.g., performance feedback, trial procedure, manipulation check, debriefing and rewarding of participants) corresponded to Experiment 1.

Results

Manipulation check. We computed mean ratings of the experimental situation and participants' perception of their coactors for each interdependency condition (see Table 1), which were then entered into separate 3 (group: Independence vs. Negative Interdependency vs. Positive Interdependency) one-way ANOVAs. Results showed that the interdependency conditions differed significantly only with respect to the cooperation/competition dimension, $F(2, 91) = 13.29$, $p < .001$, $\eta_p^2 = .23$. Post hoc t tests with Bonferroni adjustment indicated that participants in the negative interdependency condition judged the situation as more competitive ($M = 4.9$, $SD = 1.9$) than participants in the positive interdependency ($M = 2.8$, $SD = 1.4$), $t(62) = 5.16$, $p < .001$, or independence conditions ($M = 3.7$, $SD = 1.7$), $t(58) = 2.81$, $p = .02$. The ratings in the positive interdependency and independence conditions missed conventional levels of significance, $t(62) = 2.26$, $p = .08$. Interdependency conditions did not differ with respect to ratings of perceived (dis)comfort and perceived (dis)-agreeableness of the coactor (both Fs < 1). Like in Experiment 1, the interdependency manipulation selectively affected perceived cooperation/competition among pairs of participants but had no effect on each participant's mood or personal appreciation of their coactor.

Observers' memory for observed responses. We calculated mean error rates in the memory test for observed prime and probe responses separately for each interdependency condition (see Table 1), although in principle, observers' performance in the memory test is not of theoretical interest in the present experiment. Compared to the previous experiment, observers made more errors in the memory test in Experiment 2; because they had to memorize two responses instead of one together with their respective order of execution, this is not surprising. However, a 2 (display: Prime vs. Probe) × 3 (group: Interdependency vs. Negative Interdependency vs. Positive Interdependency) mixed-models ANOVA on mean error rates in the memory test yielded no significant effects (all Fs < 2.28, all ps $> .11$).

Probe performance. Only probe actors' release RTs were analyzed. According to the same criteria as in Experiment 1, 3.6% of all probe trials were excluded because of erroneous responses in prime and/or probe trials; additionally, 2.5% of all probes were excluded because of outlier values. We computed probe actors' average release RT for every condition of the factorial design and separately for each participant (see Table 2). These means were then entered into a 2 (stimulus relation: Word Repetition vs. Baseline) × 2 (response compatibility: Compatible vs. Incompatible) × 3 (group: Independence vs. Negative Interdependency vs. Positive Interdependency) mixed-models MANOVA.

Results revealed a significant main effect of response compatibility, $F(1, 91) = 157.43$, $p < .001$, $\eta_p^2 = .63$, indicating that probe actors were faster if prime and probe responses were compatible (395 ms) compared to sequences in which prime and probe responses were incompatible (427 ms). This main effect was further qualified by a Stimulus Relation × Response Compatibility interaction, $F(1, 91) = 9.81$, $p = .002$, $\eta_p^2 = .10$. Repetition of the prime word (compared to baseline) in the probe produced a significant RT benefit of $\Delta = 5$ ms, $t(93) = 3.48$, $p = .001$, if probe responses were compatible to previously executed prime responses; in turn, word repetition led to a nonsignificant RT cost of $\Delta = -2$ ms, $t(93) = 1.23$, $p = .22$, if probe actors had to execute a response that was incompatible to the previously executed prime response. This pattern of results replicates standard stimulus-response binding and retrieval effects (Rothermund et al., 2005). Importantly, the three-way interaction of stimulus relation, response compatibility, and interdependency was not significant, $F(2, 91) = 1.41$, $p = .25$, $\eta_p^2 = .03$. This finding indicates that retrieval of stimulus-response bindings was of equal magnitude for the different interdependency conditions (see also Figure 3b). Planned contrasts revealed that if anything, the Stimulus Relation × Response Compatibility interaction was stronger under independence ($S \times R_{independence} = 10$ ms, $SD = 23$ ms) compared to both interdependent conditions (however, this contrast failed the significance criterion with $t(91) = 1.63$, $p = .12$), whereas it did not differ between negative and positive interdependency ($S \times R_{negative} = 2$ ms, $SD = 15$ ms and $S \times R_{positive} = 5$ ms, $SD = 18$ ms, respectively, $|t| < 1$). Likewise, all other effects failed to reach conventional levels of significance (all Fs < 2.66, all ps $>.11$).

Joint analysis of Experiments 1 and 2. In order to test whether the three-way interaction obtained in Experiment 1 differed significantly from the (nonsignificant) three-way interaction in Experiment 2, we entered mean probe release RTs from both experiments into a 2 (experiment: 1 vs. 2) × 2 (stimulus relation: Word Repetition vs. Baseline) × 2 (response compatibility: Compatible vs. Incompatible) × 3 (group: Independence vs. Negative Interdependency vs. Positive Interdependency) mixed-models MANOVA. Most importantly, the four-way Experiment × Stimulus Relation × Response Compatibility × Interdependency interaction was significant, $F(2, 194) = 3.58$, $p = .03$, $\eta_p^2 = .04$ (further results of lower-order effects are listed in the Appendix). Planned contrasts revealed that the four-way interaction was indeed due to the contrast between independent and interdependent conditions, which was significant, $t(194) = 2.38$, $p = .01$. In turn, the second contrast (negative vs. positive interdependency) yielded no significant difference, $t(194) = 1.20$, $p = .23$.

Discussion

The results of Experiment 2 are straightforward: Participants showed a performance pattern that is consistent with standard stimulus-response binding and retrieval effects. Regardless of interdependence conditions, repeating the prime word in the probe produced a performance advantage if the to-be-executed responses in prime and probe were compatible, but led to a performance disadvantage if the to-be-executed prime and probe responses were incompatible. This finding is consistent with the idea that the prime stimulus was bound with the executed prime response and retrieved it again later, which was either appropriate or not in the probe. The fact that stimulus-based retrieval of prime responses was not affected by the interdependence relation between the pairs of participants indicated that this factor does not have a global influence on all kinds of retrieval processes. If differences in social facilitation between conditions existed at all, then they did not differentially affect retrieval processes in general.

We should mention that the results of Experiment 2 are somewhat ambiguous with respect to the issue of what is retrieved by repeating the prime stimulus in the probe because response compatibility and target feature relation were confounded in this experiment (i.e., sequences with compatible responses in prime and probe implied color repetitions, whereas sequences with incompatible responses in prime and probe involved color changes). As a result, instead of indicating stimulus-based retrieval of the prime response (which may facilitate [hamper] probe performance because the retrieved prime response is [in]appropriate in the probe), the present results might also be indicative of stimulus-based retrieval of the former prime target feature (which may facilitate [hamper] probe performance because of a perceptual feature [mis]match with the probe target). Although stimulus-response bindings are qualitatively different from stimulus-stimulus bindings, recent research findings document the emergence of multiple, independent and binary bindings within an event file; as a consequence, stimulus repetition is likely to simultaneously reflect retrieval of previous responses *and* previous targets (Giesen & Rothermund, 2013a; Hommel, 1998, 2007). In this respect, it is indeed plausible that the obtained retrieval effects in Experiment 2 in fact reflect a compound of retrieved stimulus-response and stimulus-stimulus bindings. In our view, however, this by no means compromises the overall conclusions derived from the present findings, for several reasons. First, Experiment 2 was designed to test for an influence of social facilitation on stimulus-based retrieval effects in general. In this respect, the absence of the three-way interaction in Experiment 2 indicates that *neither* retrieval of stimulus-response bindings, *nor* retrieval of stimulus-stimulus bindings are affected by social facilitation. Second, note that stimulus-based retrieval of the prime target feature cannot account for the findings of Experiment 1. Effectively, prime observers saw no target features because prime stimuli were only presented in white font to them (see Method section and Figure 2a). We thus conclude that the findings of Experiment 1 reflect genuine effects of stimulus-based retrieval of observed prime responses.

Another point that has to be discussed regards the validity of the present findings; that is, one might argue that the exclusion of the alternative account in Experiment 2 rests on a null finding (i.e., the nonsignificant three-way interaction of stimulus relation, response compatibility, and interdependency). A post hoc power analysis with G*Power 3.1 (Faul, Erdfelder, Lang, & Buchner, 2007) revealed that, in spite of the already large sample size, the achieved power in Experiment 2 was in fact rather low (i.e., the probability to detect a medium sized effect of $f = .25$ was $1 - \beta > .55$). When evaluating the results, however, one should also take into account that the findings of Experiment 2 did not only miss standard levels of significance, which might have suggested a power deficit. Instead, the actual pattern of means in Experiment 2 was contrary to the findings of the first experiment: Retrieval effects were strongest in the *independent* condition compared to the positive and/or negative interdependency condition. We hence consider it unlikely that the lack of the critical interaction effect in this experiment results from insufficient power. This reasoning is further substantiated by a joint analysis of Experiments 1 and 2, which demonstrated that the modulating effect of interdependency on stimulus-based retrieval effects (a) was evident only for observed, but not for self-performed responses; and (b) differed significantly between both experiments. By implication, this finding supports the validity of our hypothesis that mutual interdependence between coactors has a more specific modulating effect that is restricted to the stimulus-based retrieval of socially observed responses.

Although somewhat speculative and post hoc, a comparison of the effect patterns of the two experiments suggests that in the independent conditions retrieval effects were strong for self-performed behaviors but were only marginal for behaviors of other people, indicating that independence induces a focus on one's own actions.[6] To the contrary, in the interdependent conditions retrieval effects were strong and reliable for observed behaviors of others, but were rather weak for self-performed behaviors, indicating that under conditions of social interdependence, a focus on others actions is established whereas accessibility is reduced for self-performed actions.

General Discussion

To our knowledge, our study is the first that employed a sequential priming paradigm that was shared between two participants. This paradigm allowed us to investigate binding and retrieval of stimuli and observed responses in a dyadic situation. Our findings show that stimulus-response bindings can be acquired not only if a response is executed in close temporal proximity to the presence of a stimulus (Frings et al., 2007; Giesen et al., 2012;

[6] Our findings emphasize that the independent condition should not be considered as a "neutral" baseline condition. Whereas a retrieval of episodes containing one's own actions is a strong default in the independent condition (Experiment 2), no such retrieval effects occurred for episodes involving another person's actions when actor and observer were independent (Experiment 1). These findings are in line with the main conclusion that independence—like interdependence—does not exert a global effect on all retrieval processes; instead, its effect depends on what kind of behavioral information is to be retrieved from memory.

Hommel, 1998; Mayr & Buchner, 2006; Mayr, Buchner, & Dentale, 2009; Rothermund et al., 2005), but also for responses that were executed by someone else whose behavior was merely observed in combination with an eliciting stimulus. Repeating the stimulus later on leads to a retrieval of the observed response from memory, and has an influence on the active behavior of the person who has previously only passively watched the behavior of another person. This finding supports our hypothesis that stimulus-response binding and retrieval is also a basic process that is involved in social learning from observation (Bandura, 1986).

These binding and retrieval effects between stimuli and observed behaviors, however, do not occur unconditionally. Apparently, the nature of the social relation between the two participants that formed an interacting pair is crucial for the retrieval of observed responses, whereas it had no effect on standard retrieval effects for self-performed actions. In particular, stimulus-based retrieval of observed responses was apparent when participants were in an interdependent relation, but was absent for participants whose outcomes were independent of each other's behavior.

How can we account for the finding that participants in interdependent relations, but not those who worked independently of each other, retrieved bindings between a stimulus and an observed response? One possible explanation is to assume that prime observers' encoding of observed responses differed systematically between interdependency conditions. For instance, it is conceivable that prime observers in the independent condition did not attend to the responses of their coactors as carefully as the prime observers in the other conditions, so that observed responses were only poorly encoded. This in turn might have resulted in a weak stimulus-response binding, which would account for the diminished retrieval performance in the independent condition. If responses were insufficiently encoded, however, prime observers' memory for observed responses should have been selectively impaired for participants in the independent compared to both interdependent conditions, which was not the case. We thus can refute this account on the basis of the finding that memory performance did not differ between conditions, and apparently, participants in all conditions sufficiently encoded observed responses.

Our findings thus boil down to an old truth: Not everything that becomes encoded through observation will also be retrieved later (Bandura, 1986). In this respect, our findings provide convincing evidence that the cognitive system does not blindly retrieve and reactivate any observed response for action regulation. Binding and retrieval depended on the quality of the interaction situation: Observed responses had an influence on action regulation only if coactors were relevant to observers (i.e., because coactors' performance influenced whether or not participants themselves would attain the extra reward). In a similar vein, Shteynberg (2010) recently argued that people mentally prioritize information experienced by socially relevant others, meaning that the mental representation has greater cognitive accessibility and is more readily employed in cognitive operations. The present findings conform with this statement: They indicate that the acquired bindings were more likely to be employed (i.e., retrieved and reactivated) for action regulation if the observed response was executed by a relevant other, and in particular, if actor and observer were positively interrelated. This insight is indeed important, because it attests that retrieval of observed responses does not occur in an unconditionally automatic fashion once the stimulus is repeated (as is the case for self-executed responses, see Experiment 2; Rothermund et al., 2005). Stimulus-based retrieval of observed responses therefore has to be regarded as a conditionally automatic process that is contingent on mutual dependence between actor and observer.

Implications

Our findings indicate that to utilize observed responses for behavior regulation, the observer's cognitive system requires a minimum degree of connectedness to the model. In this regard, it is better to have some form of relationship than none at all; however, a positive relationship is the best way to "bridge the gap" between actor and observer. Currently, we can only speculate on the underlying mediating processes that produced these results. For instance, some authors suggest that as relationships become closer/more positive, the cognitive representations of self and other will become less distinct and more closely interconnected (Aron, Aron, Tudor, & Nelson, 1991; see also Hommel et al., 2009). Regarding the present findings, one might speculate that self-other differentiation is already reduced as a function of interdependency in goal attainment, because "being in the same boat" might foster perspective taking and increase identification with the coactor (cf. Sun & Thomas, 2013). Clearly, future research is needed to further explore the underlying mediating mechanisms that are involved in employing observed responses for automatic behavior regulation.

On the whole, the present findings attest to an implicit component of social learning processes that rests on transient stimulus-based binding and retrieval effects. On the one hand, this insight provides an important and substantial extension to (so far distinctly cognitive) accounts of behavior automatization (e.g., Hommel, 1998); on the other hand, it sheds some new light on the range of processes that are involved in and bring about social learning effects.

Conclusion

The present findings demonstrate that stimuli are integrated with responses that were merely observed in another person, and hence not executed by oneself. Subsequent stimulus repetition in turn retrieved observed responses from memory. Specifically, our findings indicate that stimulus-based retrieval of observed responses was employed for action regulation if participants' goal attainment depends on the performance of a coactor (i.e., in cooperative or competitive contexts) and in particular, if participants share a common/cooperative goal. Thus, the results attest to the flexibility of binding and retrieval processes; furthermore, they provide meaningful insight into the interplay of basal stimulus-driven processes with principles of observational and social learning.

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Appendix

MANOVA Results for the Joint Analysis of Experiments 1 and 2

Variables	*df*	*F*	η_p^2	*p*
Between-subjects				
Interdependency (I)	2	3.87*	.04	.02
Experiment (E)	1	81.81**	.30	.000
I × E	2	0.71	.01	.49
Error	194	(11,848.01)		
Within-subjects				
Stimulus relation (S)	1	11.61*	.06	.001
Response compatibility (R)	1	148.43**	.43	.000
S × I	2	0.59	.01	.55
S × E	1	2.50	.01	.12
S × E × I	2	0.16	.00	.85
R × I	2	0.79	.01	.46
R × E	1	51.34**	.21	.000
R × E × I	2	0.67	.01	.51
S × R	1	22.4**	.10	.000
S × R × I	2	1.60	.02	.21
S × R × E	1	1.95	.01	.16
S × R × I × E	2	3.58*	.04	.03
Error (S)	194	(117.47)		
Error (R)	194	(556.15)		
Error (S × R)	194	(171.2)		

Note. Values enclosed in parentheses represent mean square errors. *df* = degrees of freedom.
* $p < .05$. ** $p < .01$.

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