Atten Percept Psychophys (2014) 76:1242–1252
DOI 10.3758/s13414-014-0652-0

Decomposing the action effect: How simple actions affect subsequent perception

Blaire J. Weidler · Richard A. Abrams

Published online: 14 March 2014

Abstract Simple actions toward an object cause people to allocate attention preferentially toward properties of that object in subsequent unrelated tasks. We show here that it is not necessary to process or attend to any properties of the object in order to obtain the effect: Even when participants knew prior to the object's onset that they would be acting, the effects of the object remained. Furthermore, the effect remained when the action had no visible effect on the object. In addition, we examined the extent to which the effect may be due to goal updating (which is necessary only on trials that require action) and found that the effect remained even when goal updating was not necessary. The results reveal that a simple action does, indeed, affect perception and have implications for understanding vision as individuals make actions in naturally occurring behavior.

Keywords Visual search · Perception and action

The effect of simple actions on perception

It has been known for some time that perception is used to guide action (e.g., Woodworth, 1899). However, it has only recently been established that this interaction goes both ways: Action can also affect perception. For example, one's ability to interact with the environment can affect perception: The ability to reach an object with a tool scales perception so that such objects are perceived to be closer than when a tool is unavailable (e.g., Bloesch, Davoli, Roth, Brockmole, & Abrams, 2012; Davoli, Brockmole, & Witt, 2012; Witt, Proffitt, & Epstein, 2005).

Other research has indicated that preparation of an action can affect subsequent perception. For example, Deubel and Schneider (1996) illustrated that target discrimination is facilitated at the location of a planned saccade, as compared with other nearby locations to which an action was not planned. In addition, planning a specific type of hand movement can affect perception. For example, when individuals are preparing to grasp an object, they become more sensitive to features relevant to grasping (e.g., orientation or size) than to those irrelevant to grasping (e.g., color or luminance; Bekkering & Neggers, 2002; Wykowska, Schubö, & Hommel, 2009). In addition, specific grasps facilitate grasp-relevant perception: When participants prepared to make a power grip, they detected large objects more quickly than small objects in a change blindness paradigm, whereas when they prepared a precision grip, detection of smaller objects was facilitated (Symes, Tucker, Ellis, Vainio, & Ottoboni, 2008).

Recently, Buttaccio and Hahn (2011) examined another way in which action affects perception—specifically, how a simple response directed toward an object might affect perception. Unlike prior research that investigated how the ability to act or the preparation of an action affects online perception, Buttaccio and Hahn (2011) were interested in determining how an action toward an object will affect *subsequent* deployment of attention toward objects with similar attributes. Specifically, in their initial experiment, the authors presented participants with a cue consisting of a color name (e.g., "blue") followed by a colored shape, the *prime*. If the color name matched the color of the prime (e.g., if the shape was also blue), participants were instructed to respond with a manual keypress as quickly as possible (*go* trial). If the word cue did not match the color of the shape (e.g, "blue" was followed by a green shape), the participant did nothing but view the prime (*no-go* trial). Following a brief delay,

B. J. Weidler · R. A. Abrams
Washington University in St. Louis, St. Louis, MO, USA

B. J. Weidler (✉)
Department of Psychology, Washington University, 1 Brookings Drive, St. Louis, MO 63130, USA
e-mail: blaire.weidler@gmail.com

participants performed a visual search task. Although the prime color was uninformative, participants were faster to find the target if it appeared in the prime's color, as compared with when a distractor appeared in the prime's color. Importantly, that effect occurred only on the go trials, when the subject had produced an action directed toward the prime (and hence, we refer to the phenomenon as the *action effect*). After a no-go trial, there was no reaction time (RT) advantage if the target was in the prime's color. Buttaccio and Hahn reasoned that the action effect arose because acting on an object strengthened the object's "trace" (e.g., Buttaccio & Hahn, 2011, p 1454). Subsequently, when already-strengthened features match those in the visual search display, attention is preferentially directed toward objects with those features, producing the RT advantage, but only on the go trials.

Buttaccio and Hahn (2011) also investigated the extent to which color priming may have played a role in their results. In their Experiment 4, they altered the action task so that participants acted on a *mismatch* between the color-word and the color of the prime object and refrained from acting upon a match. The authors compared the data from the match (no-go trials) in that experiment and the match (go trials) in the previously described Experiment 1 (identical to Experiment 4, with the exception of the altered action instructions) to determine whether color priming could account for the action effect. The data revealed an action ×validity interaction, because there was a difference based on validity only following an action, but not when there was a match but no action. These results effectively rule out the possibility that the action effect was caused merely by the match between the color-word and the prime and, instead, reaffirm that it is caused by the action per se. One goal of the present research is to extend these findings by equating go and no-go conditions more completely within a single experiment.

Of course, it has been known for some time that what has been previously seen or responded to can affect attentional allocation in subsequent visual search (see, e.g., Kristjánsson & Campana, 2010, for a review on repetition priming).[1] But research on the action effect extends such findings in two ways. First, by directly manipulating action, this research makes clear that acting toward an object affects perception of the objects' features in a different way than just viewing the object. In addition, the action effect reveals that a response to a single object (e.g., one that does not need to be selected from among distractors) can bias subsequent visual attention toward that object's properties on an unrelated task. Furthermore, the finding suggests that the perceptual consequences of actions in daily life may persist beyond the moment of action—having implications for many daily activities that require coordination between manual action and vision (e.g., driving). However, many questions about this important finding still remain—specifically, about the conditions necessary to produce the effect and about the underlying mechanisms. In the present article, we address some of these questions.

There were three main goals in the present set of experiments. After conceptually replicating Buttaccio and Hahn's (2011) main finding of the action effect (Experiment 1), the first goal was to determine whether it is necessary for the action to have a consequence in order to obtain the effect (Experiment 2). The second goal was to examine the extent to which processing properties of the acted-on object is needed to obtain the action effect (Experiment 3), and the third was to examine the extent to which a viable alternative explanation (*temporal goal updating*) might account for the effect (Experiment 4). To anticipate the findings, the action effect was successfully replicated, the presence of a visible effect of the action is not necessary to obtain the effect, nor is processing of the prime. Finally, the action effect cannot be attributed to temporal goal updating.

Experiment 1

Experiment 1 was a conceptual replication of Buttaccio and Hahn's (2011) original demonstration of the action effect. On each trial, participants decided whether to act on an object on the basis of the match between a presented word and the object's color. They then completed an unrelated visual search task. Evidence for the action effect would arise if, after acting on an object but not after merely viewing it, participants respond faster in the search task when the target is contained in the color of the object from the action task than when that color contains a distractor.

Method

Participants

Twelve undergraduates participated for course credit.

Apparatus

Participants sat and viewed a CRT display (100-Hz refresh rate) binocularly from a distance of 35 cm, with position fixed by a chinrest.

Stimuli and procedure

Figure 1 shows the sequence of events for all experiments. On each trial, participants saw a 2° white fixation cross presented

[1] In addition, Hommel (e.g., 1998, 2004) and colleagues have investigated how the creation of *event* files (episodic memory traces representing features of a stimulus object and a motor response) and repetition of motor response and object features can affect perception. We discuss the relation between the current findings and event files in the general discussion.

at the center of the black screen for 500 ms. Next, a color word ("red," "yellow," "green," "blue," "purple," or "gray"; in white letters 2° in height) appeared at the center of the screen for 500 ms. After another identical fixation cross appeared for 130 ms, a colored (red, yellow, green, blue, purple, or gray; the *critical color*) circle (*the prime*), 6° in diameter, appeared at the center of the screen for 750 ms or until response. On *go* trials, the color word and the colored circle matched (e.g., the word "blue" was followed by a blue circle). On *no-go* trials, the colored word and the circle did not match (e.g., the word "blue" was followed by a purple circle). On each trial, participants had two tasks—the action task and the search task. For the *action task,* participants were instructed to press the space bar as quickly as possible if the color of the circle matched the word (the go trials) and to do nothing if the word and circle did not match (the no-go trials).

After the prime offset, a fixation cross appeared for 500 ms, during which time participants received auditory feedback (a beep) if their response to the action task was incorrect. Next, a two-item search array appeared containing two 6°-diameter colored circles with a 4° × 0.12° black line embedded in the center of each. One of the circles was in the critical color (the one seen in the action task). On each trial, one line was vertical and one was tilted (−3° or 3°), and in the *search task,* participants were to indicate the tilt of the sole tilted line by pressing the left or right arrow key. The circle containing the target line and the circle containing the distractor line appeared in two of five predetermined locations (set around an imaginary circle with radius of 12°) on each trial.

On *valid* trials, the tilted line target appeared in the circle that was the same color as the circle previously seen during the action task in that trial, and on *invalid* trials, a vertical distractor line appeared in that color. The second color in the display was always different from the critical color. It is important to note that with two items in the search display and 50 % valid (and 50 % invalid) trials, there was no task incentive for participants to allocate attention toward the seen or acted-on color first; on each trial, that color was just as likely to contain a target as a distractor. The search display remained visible for 1,500 ms or until response. This was followed by a 1,500-ms intertrial interval, which included 500 ms of both visual and auditory feedback ("Too slow!" or "Incorrect!" and a beep) to slow or incorrect responses. All instructions were presented on the screen and were read aloud by the experimenter.

Design

Participants performed 12 practice trials with the experimenter present, followed by 144 test trials alone. The trials were presented in random order from the group of 144, and participants had a break after every 36 trials. Participants received feedback about average RT for both action and search tasks after the practice trials and halfway through the test trials, as well as accuracy feedback halfway through the test trials. The 144 test trials consisted of a base group of 24 (2 action × 2 validity × 6 colors) repeated 6 times. On no-go trials, the color of the word seen initially during the action task was selected randomly from the remaining five colors. The location of the two circles (among the five predetermined locations), the second color in the search display (in addition to the critical color), and the tilt of the target line were also chosen randomly on each trial.

Results

Action task

Participants were highly accurate in the action task ($M = .983$, $SD = .018$), and accuracy did not differ between the go ($M = .983$, $SD = .017$) and no-go ($M = .984$, $SD = .027$) trials, $t(11) < 1$. Average median RT on correct go trials for the action task was 355 ms ($SD = 37$).

Search task

Accuracies for each condition are shown in Table 1. Participants responded correctly in both the action and search tasks on .942 ($SD = .042$) of trials. Furthermore, this conjoined accuracy did not differ as a function of action, $F(1, 11) = 3.30$, $p = .097$, or validity, $F(1, 11) = 1.94$, $p = .191$, nor did the factors interact, $F(1, 11) = 3.01$, $p = .111$. Median search RTs from trials on which both tasks were correct were submitted to a 2 (action: go or no-go) × 2 (validity: valid or invalid) repeated measures analysis of variance (ANOVA) and can be seen in Fig. 2. There was a main effect of validity, with faster responses to valid trials, $F(1, 11) = 23.04$, $p =.001$, $n^2_p = .68$. Participants were slower overall to respond in the search task on go, as compared with no-go trials, $F(1, 11) = 5.41$, $p =.040$, $n^2_p = .33$. In addition, in a replication of the action effect, action and validity interacted, $F(1, 11) = 31.85$, $p < .001$, $n^2_p = .74$. In accord with Buttaccio and Hahn's (2011) findings, participants were slower to respond on invalid than on valid trials on go trials (when they acted on the object), $t(11) = 8.71$, $p < .001$, but not on no-go trials (when they were simply exposed to the object), $t(11) = 1.50$, $p = .163$.

Discussion

This experiment replicated Buttaccio and Hahn's (2011) action effect. Participants responded to an object with a space bar press if the color of the object matched a previously presented word and refrained if the color and word did not match. Then, on an unrelated visual search task, the color of the previously seen object influenced allocation of attention *only* when the object had been acted on. Following an action, participants were faster to find the target if it was in the color they acted in response to

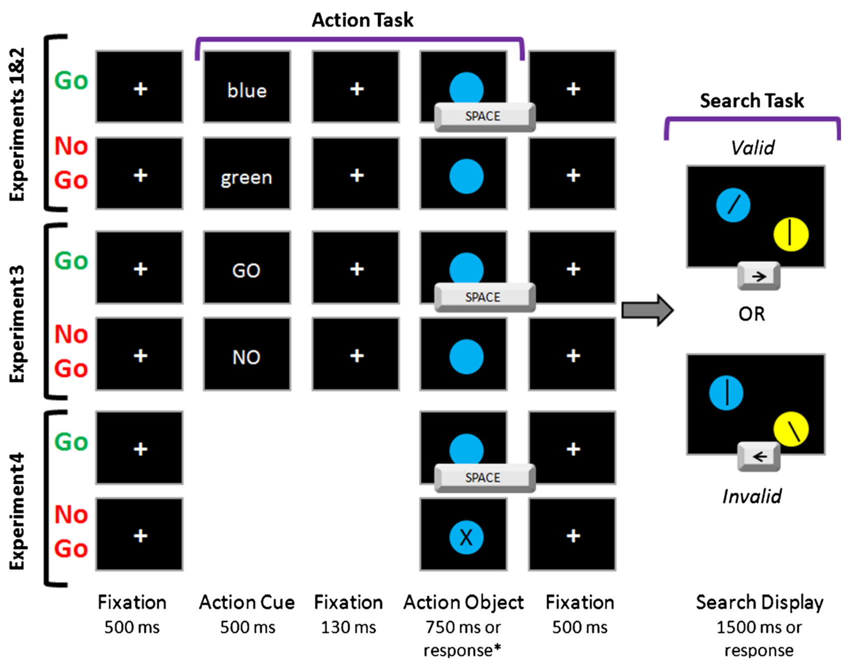

Fig. 1 Method for all experiments. In the action task, participants were required to press the space bar on go trials but to do nothing on no-go trials. The instructions for the action task differed across experiments (see text for additional details). In the search task, participants found the sole tilted line and indicated its tilt direction by pressing one of two keys. On valid trials, the tilted line was in the previously seen color; on invalid trials, that color contained a distractor. The figure is not drawn to scale. *Note that in one condition of Experiment 2, the prime always remained on screen for 750 ms (see text for details)

than if that color contained a distractor. However, when participants just viewed the colored object without responding, they were no faster to find the target whether it was in that color or not, revealing a unique effect of action.

Experiment 2

The action performed in Experiment 1 in response to the prime had an instantaneous effect on the prime; it was immediately removed from the screen. Indeed, most actions that people perform in daily life have immediate consequences (e.g., a letter appears on a computer screen, a water fountain turns on). However, it is not known whether the immediate consequence of the action is necessary for producing the action effect. To investigate that, in one condition of the present experiment, the prime remained on the screen for a fixed duration regardless of whether an action was performed or not. This change also equated the duration of exposure to the prime across the go and no-go conditions, allowing an examination of any possible effects of that difference.

Method

Participants

Twelve undergraduates participated for course credit.

Apparatus, stimuli, procedure, and design

Experiment 2 was identical to Experiment 1, except for the following changes. The participants completed two tasks in a

Table 1 Mean proportion of conjoined accuracy (when both action and search task were correct) by trial type for all experiments (with standard deviations in parentheses)

Experiment	Go		No Go	
	Invalid	Valid	Invalid	Valid
1	.9306 (.0716)	.9676 (.0232)	.9329 (.0574)	.9375 (.0518)
2 (offset)	.9305 (.0435)	.9583 (.0402)	.9629 (.0298)	.9444 (.0443)
2 (no offset)	.9514 (.0445)	.9629 (.0298)	.9352 (.0432)	.9560 (.0323)
3	.9384 (.0427)	.9420 (.0383)	.9469 (.0354)	.9420 (.0410)
4	.9306 (.0486)	.9375 (.0484)	.9167 (.0574)	.9345 (.0598)

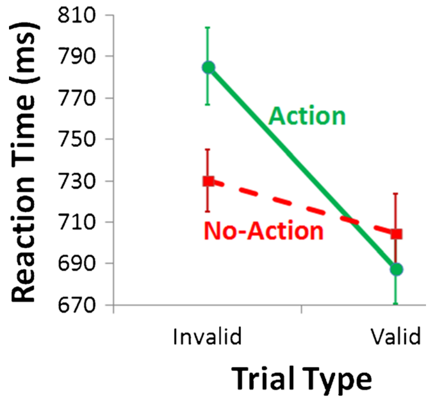

Fig. 2 Reaction times (RTs; mean of each participant's median RT) for the search task as a function of action and validity from Experiment 1. Action and validity interacted: Following an action, valid trials were faster than invalid trials, whereas validity did not influence search RTs after no action. Error bars depict standard errors of the means

counterbalanced order. The first task was an exact replication of Experiment 1 (offset condition). The second task was identical to the first task except that, during the action task, the circle did not offset upon a space bar press (no-offset condition). Instead, the circle remained visible for 750 ms on *all* (i.e., both go and no-go) trials.

Results

The independent variable referring to whether the prime offset upon keypress in the action task will be referred to as *action consequence.*

Action task

Performance on the action task was again highly accurate (offset, M = .990, SD =. 006; no offset, M = .992, SD =.010) and accuracy did not differ as function of action consequence or action trial type, nor did the factors interact (Fs < 1). Average median RT on correct go trials for the action task (offset, M = 350, SD = 26; no offset M = 346, SD = 27) did not differ as a function of action consequence, $t(11) = 1.25$, p = .239.

Search task

Accuracy Participants performed both the action and search tasks correctly on .949 (SD =.027) of the offset trials and .951 (SD = .023) of the no-offset trials, and this conjoined accuracy did not differ by action consequence ($t < 1$). Conjoined accuracy data were submitted to a 2 (action consequence) × 2 (action type) × 2 (validity) ANOVA. There was no effect of action on accuracy ($F < 1$); however, performance was slightly better on valid (.955) than on invalid (.945) trials, $F(1, 11)$ = 3.49 , p =.088. Action and validity did not interact in the accuracy data, $F(1, 11) = 3.52$, p =.087; however, the pattern mirrored the typical action effect: Following an action, performance was better for valid (.961) than for invalid (.941) trials, but after viewing the object, accuracy did not differ as a function of validity (valid M = .950, invalid M = .949). In addition, the accuracy data revealed a marginal three-way interaction, $F(1, 11) = 4.71$, p =.053, $n^2_p = .30$. This occurred because, in the offset condition, action and validity interacted, $F(1, 11) = 10.58$, p =.008, $n^2_p = .49$ (go invalid =, go valid =, no valid, no invalid), but action and validity did not interact in the no-offset condition ($F < 1$).

Response time RTs for the search task are shown in Fig. 3. A 2 (action consequence) × 2 (action type) × 2 (validity ANOVA) revealed only a main effect of validity, $F(1, 11) = 43.94$, p <.001 , $n^2_p = .80$, and an action × validity interaction, $F(1, 11)$ = 34.54, p <.001 , $n^2_p = .76$. Importantly, the critical action ×validity interaction was present in both the typical offset, $F(1, 11) = 16.63$, p =.002 , $n^2_p = .60$, and no-offset, $F(1, 11)$ = 14.40, p =.003 , $n^2_p = .57$, conditions, and the action effect did not differ in magnitude across action consequence condition ($F < 1$ for the three-way interaction). Following an action, participants found the target faster during valid than during invalid trials in both the offset condition, $t(11) = 6.25$, p < .001, and no-offset condition, $t(11) = 5.16$, p < .001. However, when participants just viewed the object, RTs did not differ as a function of validity in the offset, $t(11) = 1.27$, p = .23, or no-offset, $t < 1$, conditions.

Discussion

Given that actions in daily life typically have immediate visual consequences, it is plausible that the action effect would not occur if participants' actions did not have a consequence. In this experiment, we examined whether the action effect would occur when the action had no consequence (the prime remained on screen after participants' response). In addition, this procedural change allowed us to equate the duration of participants' exposure to the prime in the go and no-go conditions. We found a robust action effect both in the typical offset condition and in the no-offset condition, and the magnitude of the effect did not differ as a function of the action's consequence. This indicates that neither an action consequence nor the differential duration of prime exposure across conditions is critical to obtain the action effect. Given this result, we will utilize the prime offset method for the remainder of the experiments in this article.

Experiment 3

All previous investigations of the action effect (including Experiments 1 and 2) have required that participants process the prime to some extent—whether it was to evaluate its color,

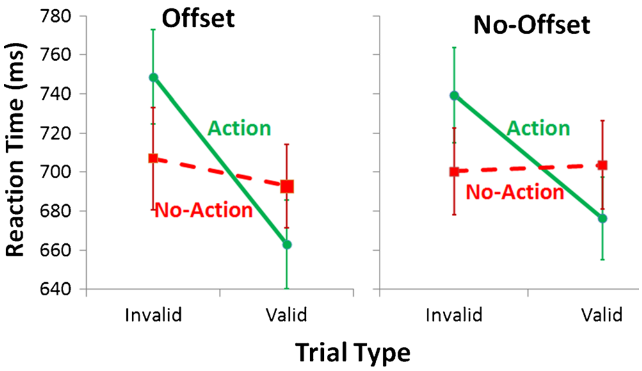

Fig. 3 Reaction times for the search task as a function of action and validity in both the offset and no-offset conditions of Experiment 2. In both the offset condition, when the circle offset on response, and the no-offset condition, when the circle remained on the screen following the action, action and validity interacted to reveal the action effect. Error bars represent standard errors of the means

its shape, or the identity of a target embedded inside it (Buttaccio & Hahn, 2011). This leaves open the possibility that processing of the prime, in combination with the action, is critical for the action effect. In this experiment, we investigated the extent to which processing of the acted-on object is necessary. In the experiment, participants knew in advance whether or not they would respond to the prime, regardless of its properties. Thus, no processing of the object was required at all (other than to detect its onset). Finding the action effect under these conditions would provide evidence that it is specifically the action itself—not the action in conjunction with any processing of the objects' properties—that is driving the effect.

Method

Participants

Twenty-four undergraduates participated for course credit.

Apparatus, stimuli, procedure, and design

The apparatus, stimuli, and procedure were identical to those used in Experiment 1, with the following exceptions. Instead of seeing a colored word, participants saw the word "GO" or "NO" for 500 ms prior to presentation of the colored circle. In the action task, participants were instructed to press the space bar to the next object that appeared following the word "GO" (go trials) and do nothing following the word "NO" (no-go trials; see Fig. 1). As a reminder, the color of the circle in the action task always reappeared in the search array, but half the time it contained a target (valid trials) and half the time it contained a distractor (invalid trials).

Results

One participant was removed from the analysis for having combined accuracy below 80 % in at least one of the four action × validity combinations.

Action task

Performance on the action task was again highly accurate ($M = .985$, $SD = .011$), but participants performed slightly poorer on the go ($M = .980$, $SD = .020$) than on the no-go ($M = .990$, $SD = .011$) trials, $t(22) = 1.88$, $p = .073$. Average median RT on correct go trials for the action task was 248 ms ($SD = 53$). Space bar responses in this experiment were much faster than comparable responses in Experiment 1 (354 ms), $t(33) = 6.21$, $p < .001$, and Experiment 2 offset (350 ms), $t(33) = 6.26$, $p < .001$ and no-offset (346 ms), $t(33) = 6.00$, $p < .001$, conditions. This reflects the fact that processing of the object was required in Experiments 1 and 2 prior to action, but it was explicitly not required here.

Search task

Participants performed both the action and search tasks correctly on .942 ($SD = .023$) of the trials. As in Experiment 1 and 2, conjoined accuracy did not differ as a function of action or validity, nor was there an interaction between the two factors (all Fs < 1; see Table 1). Figure 4 shows the median search RTs for correct trials. The effects of action and validity interacted, $F(1, 22) = 5.21$, $p = .032$, $n^2_p = .19$: As in Experiments 1 and 2, following an action, participants found the target more quickly on valid than on invalid trials, $t(22) = 3.96$, $p < .001$, but there was no effect of validity on no-go trials, $t < 1$. In addition, a main effect of validity indicated shorter RTs to valid than to invalid trials, $F(1, 22) = 8.95$, $p = .007$, $n^2_p = .29$.

Discussion

The findings from this experiment show that it is not necessary to process, or make any decision about, the object that is being acted on in order to obtain the action effect. On each trial, participants were cued with the word "GO" or "NO," and on go trials, they knew that they would be acting on the next object that appeared—regardless of any of its physical properties. Consistent with the belief that participants would spend less time examining the acted-on object in this experiment than in Experiments 1 and 2, space bar responses on go trials were much faster in the present experiment than in Experiments 1 and 2. Despite the briefer exposure and the absence of any required decision about the colored object, we again found evidence for the action effect; after an action, participants found the target faster on valid than on invalid trials,

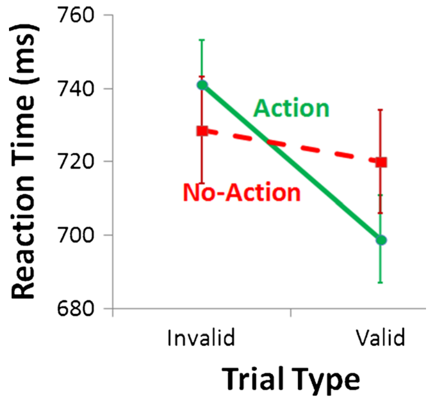

Fig. 4 Reaction times (RTs) for the search task as a function of action and validity from Experiment 3. As in Experiments 1 and 2, action and validity interacted: Following an action, valid trials were faster than invalid trials, whereas validity did not influence search RTs after no action. Error bars depict standard errors of the means

whereas there was no difference in RTs as a function of validity after merely viewing the object.

Experiment 4

The results of Experiment 3 provide evidence that it is the action itself—and not any processing or decision made about the prime—that causes the action effect; a preplanned response to the mere onset of a task-irrelevant object caused validity effects. However, recent research has highlighted the possibility that the effects that have thus far been attributed to action may just be an artifact of temporal goal updating (Makovski, Jiang, & Swallow, 2012). Specifically, Makovski et al. showed participants pictures of faces and asked them to press a key when they saw a face of a certain gender. A subsequent recognition test revealed that images that received a keypress response at encoding were better remembered. However, the authors pointed out that this pattern could occur because of action *or* because of temporal goal updating. According to the temporal goal updating explanation, if, on each trial, participants assume a default state of no action, then action trials, but not no-action trials, would require an updating of that goal. In order to adjudicate between the two accounts, Makovski et al. manipulated participants' default state by telling them to respond to each image that appeared but to refrain on some trials (e.g., respond to all but female faces). They reasoned that if action is enhancing memory, images that participants acted on should be better remembered, regardless of the default instructions. But, if temporal updating is responsible, images that did not receive a buttonpress should be better remembered, since those trials required goal updating from the default state of acting. In support of the temporal updating account, memory was better for images to which participants did not respond. Thus, in their experiment, it was the updating of the goal that enhanced memory, and not the production of an action. This leaves open the possibility that the results reported by Buttaccio and Hahn (2011) may have been caused by the same mechanism—specifically, goal updating, and not acting.

The present experiment evaluated the extent to which temporal goal updating may be responsible for the findings that have been, until this point, attributed to action. In order to manipulate participants' default state, participants were told to respond to the object they saw during the action task on every trial, except in certain circumstances. If the temporal updating account is correct, there should be evidence for shorter RTs on valid than on invalid trials in the no-go condition (when temporal updating is necessary), but not on go trials, because participants are assuming they will act on each trial. However, if the action account is correct, there should be validity effects on the go trials, when participants make a response to the object, but not on the no-go trials when they do not.

Method

Participants

Twenty-four undergraduates participated for course credit.

Apparatus, stimuli, procedure, and design

This experiment was identical to Experiment 1, with the following exceptions. There were no words presented; after a 500-ms fixation, a colored circle appeared. The circle contained a black "X" (3° in height) on one third of the trials (see Fig. 1). For the action task, participants were told to press the space bar as quickly as possible in response to any circle that appeared (go trials), unless the circle had an "X" in it (no-go trials).

Results

Three participants were removed from the analysis for having combined accuracy below 80 % in at least one of the four action × validity combinations.

Action task

Participants' accuracy on the action task was .985 ($SD = .011$), and participants exhibited higher accuracy when making a response on go trials ($M = .992$, $SD = .009$) than when withholding a response on no-go trials ($M = .972$, $SD = .029$), $t(20) = 2.90$, $p = .009$. This pattern is opposite of that of Experiment 3 ($M_{go} = .980$, $M_{no\text{-}go} = .990$), and a 2 (action: go or no go) × 2 (experiment: 3 or 4) analysis revealed that the pattern indeed reversed across experiments. There was no main effect of experiment (F < 1) or action type, $F(1, 42) = 1.35$, $p = .252$, but the two factors interacted, $F(1, 42) = 12.12$,

p = .001, n^2_p = .22. This indicates that the manipulation successfully altered participant's default state from "don't act" to "act."

Median RT on the go trials was 348 ms (SD = 37), which was comparable to RTs for this task in Experiment 1 and both action consequence conditions of Experiment 2, $ts < 1$, and longer than RTs for this task in Experiment 3 (248 ms), $t(42)$ = 7.22, $p < .001$.

Search task

Conjoined accuracy on both tasks was .931 (SD = .042), and there was no main effect of validity, $F(1, 20) = 2.51$, p = .129, of action, nor did the factors interact (both $Fs < 1$; see Table 1). As can be seen in Fig. 5, in the correct search RTs, there was no main effect for action or validity, $Fs < 1$; however, importantly, the two factors interacted, $F(1, 20) = 16.86$, p = .001 , n^2_p = .46. As in Experiments 1–3, on go trials, participants found targets more quickly on valid than on invalid trials, $t(20) = 3.98$, $p < .001$. However, unlike in prior experiments, on no-go trials, participants found the targets more *slowly* on valid than on invalid trials, $t(20) = 2.78$, p = .012.

Discussion

In this experiment, we assessed the extent to which temporal goal updating may be responsible for effects previously attributed to action. In order to do that, by manipulating instructions and response probabilities, we changed the participants' default state to the presumption of action. The typical action effect was still observed, clearly indicating that temporal updating is not responsible for preferential allocation of attention toward properties of an acted-on object: Even when participants planned to respond on each trial (so that was their default state), on go trials, search RTs were shorter on valid than on invalid trials. Therefore, it seems that simple actions do have a unique effect on attentional allocation.

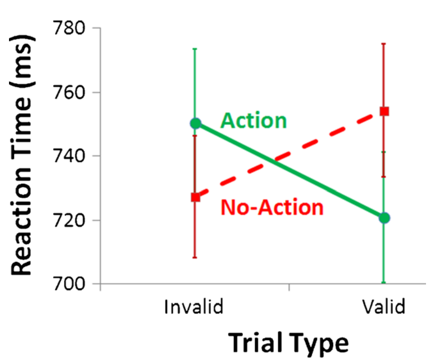

Fig. 5 Reaction times for the search task as a function of action and validity for Experiment 4. Action and validity interacted; on go trials, participants were faster on valid than on invalid trials, whereas on no-go trials, the pattern reversed. Error bars depict standard errors of the means

It is important to note that the accuracy data from the action task provide evidence that participants did indeed change their default state to the presumption of action. As in Makovski et al.'s (2012) Experiment 4, our participants were more accurate on go than on no-go trials in the action task. Makovski et al. argued that this pattern of poorer performance withholding a response on no-go trials indicates that participants were planning to act on all trials. As a comparison, in Experiment 3, participants performed more poorly in the action task on go than on no-go trials. This pattern of better performance on no-go trials is expected if, as Makovski et al. suggested, when not given explicit instructions to act on each trial, participants' expected state is to not act.

In addition, this experiment revealed a novel finding concerning the no-go trials. When participants just viewed the colored shape and did not respond, we found a *reverse* validity effect; participants were slower to find the target on valid trials if it was in the color they had just viewed than on invalid trials when that color contained a distractor. This is a markedly different pattern than has been seen for the no-go trials of the other experiments reported in the present article or in the prior literature and will be further addressed in the General Discussion section.

General discussion

The present set of experiments advances the action effect initially reported by Buttaccio and Hahn (2011). The action effect occurs when a simple action directed toward an object subsequently preferentially biases visual attention toward a feature—in this case, the color—of that object. The present study replicated the basic effect across four experiments. In addition, Experiment 2 illustrated that it is not necessary for action to have a consequence in order to obtain the effect. Experiment 3 showed that the action effect still occurs when participants know they are going to respond prior to the object's appearance and, therefore, don't need to process any of the acted-on object's properties to perform the task. This indicates that a simple action performed in response to an onset is sufficient to affect subsequent attention allocation.

Experiment 4 addressed the possibility that the effect previously attributed to action may be due not to acting at all but, instead, to temporal goal updating. However, Experiment 4 revealed that even when action trials required no goal updating, there was still evidence for the action effect. In addition, that experiment revealed an interesting novel finding: When participants planned to act on each trial but then refrained on a subset of trials, during the search task, they were slower to find the target if it was in the color that they had viewed but not acted on. This effect will be discussed further later.

First, now that it has been more firmly established that simply directing a preplanned action towards an object will create the action effect, it is possible to consider the mechanism that may underlie the phenomenon. As was previously noted, Buttaccio and Hahn (2011) argued that when participants perform a simple action on an object, it increases the strength of the properties of that object (the "trace"; e.g., p. 1465). Additionally, they postulated that the enhanced trace alters how specific features (in this case, the critical color) are weighted in the subsequent visual search task. When participants then view the search array with the goal of searching for a target (a tilted line irrespective of color), the enhanced attentional weight of the critical color following an action competes with the task goal, and visual attention is allocated to the critical color preferentially. This will shorten RTs on valid trials when the target is in the critical color and lengthen RTs on invalid trials when a distractor is in the critical color.

Event files

What mechanism might underlie the enhanced weight of the prime color? One possibility involves the properties of stimulus–response *event files*. Event files are episodic memory traces that temporarily link together features and actions associated with an event. When participants respond to a stimulus, such as the prime in the present experiments, their response becomes bound into an event file along with features of the acted-upon object (e.g., Hommel, 2004). The contents of the event file may then subsequently affect attentional weighting during search, leading to the action effect that we have reported. Indeed, recent research has indicated that the contents of working memory can affect allocation of visual attention (e.g., Olivers, Peters, Houtkamp, & Roelfsema, 2011; Soto, Heinke, Humphreys, & Blanco, 2005). Although it is not clear to what extent event files may additionally rely upon working memory, they would seem to contain the necessary information that could bias visual attention toward objects sharing the acted-on color.

Repetition priming

Another potential explanation for the action effect is that it may represent a special case of *repetition priming*. Repetition priming occurs when visual attention is preferentially allocated to previously seen features, particularly those that were important for previous tasks or behavioral goals (see, e.g., Kristjánsson & Campana, 2010, for a review). For example, if the target on the current trial happens to be red, performance will be facilitated if the target on the previous trial was also red, as compared with another color (e.g., Maljkovic & Nakayama, 1994). Thus, it seems possible that in the present experiments, when participants responded to the prime, features of the responded-to object may have been similarly primed for the subsequent visual search task, leading to shorter RTs on valid than on invalid trials.

Nevertheless, there are some differences in the procedures used in the present experiments compared to those typically used to investigate repetition priming. Specifically the effects of priming are typically measured following a trial in which participants search for and respond about a specific target among distractors (e.g., Huang, Holcombe, & Pashler, 2004; Maljkovic & Nakayama, 1994). In contrast, the present procedure employed a response (or not) to a simple onset followed by a search in alternating fashion.

Despite that difference, there are a few reasons to believe that priming mechanisms may be playing a role in the action effect. First, research has revealed that nonsearch tasks can create priming effects in search tasks (as is the case in the present experiments; Brascamp, Blake & Kristjánsson, 2011). In addition, if priming mechanisms are involved, a recent study examining the difference between active and passive trials may shed some light on why there are validity effects following an action toward an object, but not after just viewing the same object. Kristjánsson, Saevarsson and Driver (2013) found evidence for priming only for *active* trials (when participants responded to the target with a keypress), but not for *passive* trials (when participants simply viewed the display containing a pop-out object; but see Yashar, Makovski & Lamy, 2013). Therefore, if repetition priming mechanisms underlie the action effect, it may not be surprising that acting, but not viewing an object, causes preferential attentional allocation.

In addition, it is worth noting that unlike some other features, color tends to result in priming even when color is irrelevant either for locating the target or for performing the necessary task discrimination (Kristjánsson, 2006). This was the case in Experiments 3 and 4 when neither motor response in the action or the search task was based on color (one to onset, the other to orientation). Therefore, given that color was the feature used to manipulate validity in the present study, the conditions were conducive to observing priming effects.

Reverse validity effect

In addition to ruling out the possibility that temporal updating is responsible for the action effect, Experiment 4 yielded another interesting finding not seen previously. In Experiment 4, when participants planned to act on all trials, the subset of trials that did not require acting led to reversed validity effects in the search task: Participants were *slower* to find the target if it was embedded in the color they had previously seen than if that color contained a distractor. It is possible that this pattern arose through a mechanism similar to the priming mechanism discussed earlier. Except in this case, a *negative* priming mechanism, in which it is more difficult to return attention to a previously ignored stimulus, may be contributing (for reviews, see, e.g., Fox, 1995a, b; May, Kane, & Hasher, 1995).

Relation to other action research

While the present research focuses on how simple actions affect subsequent perception, recent research has also focused on other ways in which action can affect perception. For example, the *action-specific perception* account postulates that individuals' perception will be scaled by their momentary ability to interact with the environment (e.g., Witt, 2011). In support of that idea, individuals who were having difficulty engaging with the environment (e.g., because they are fatigued or carrying a heavy load; Bhalla & Profitt, 1999) would perceive the slope of hills to be steeper than would individuals who were not having difficulty engaging with the environment (e.g., rested or unburdened).

In addition, preparing actions can affect perception. For example, after preparing a specific type of action (e.g., grasping vs. pointing), the perceptual system becomes more sensitive to features relevant to that action (e.g., size vs. luminance; Wykowska et al., 2009). Other recent research indicates that individuals' body posture (e.g., the position of their hands relative to the stimuli) can affect their perception (e.g., Abrams, Davoli, Du, Knapp, & Paull, 2008). These changes in perception when participants' hands are near the stimuli often been attributed to participants' altered ability to act upon the environment while in that posture (e.g., Gozli, West, & Pratt, 2012).

The present research on the action effect highlights another way in which action can affect perception—in this case, subsequent perception. When participants act in response to an object, its features become prioritized in future tasks. Therefore, in addition to features that are relevant for the upcoming action becoming prioritized perceptually when one is preparing an action (e.g., Wykowska et al., 2009), research on the action effect indicates that features that are acted on become prioritized in the future. Furthermore, the present findings may fit with the action-specific perception account. If individuals' perceptions are scaled by their ability to act on the environment, then when individuals view an object that has recently been acted on (as is the case during the search task on "go" trials of the present experiments), perception of that object may be facilitated because recent experience confirmed that action toward that object is possible. In summary, the present results add support to the growing understanding of how actions can affect how we perceive the world around us. It appears that just simply responding to the onset of a stimulus confers a special status to its properties that draws attention to similar stimuli later. Further research will be necessary to determine the specific mechanisms underlying the effect and the broader implications of the phenomenon.

References

Abrams, R. A., Davoli, C. C., Du, F., Knapp, W. H., & Paull, D. (2008). Altered vision near the hands. *Cognition, 107,* 1035–1047. doi:10.1016/j.cognition.2007.09.006

Bekkering, H., & Neggers, S. (2002). Visual search is modulated by action intentions. *Psychological Science, 13,* 370–374. doi:10.1111/j.0956-7976.2002.00466.x

Bhalla, M., & Proffitt, D. R. (1999). Visual–motor recalibration in geographical slant perception. *Journal of Experimental Psychology: Human Perception and Performance, 25,* 1076–1096. doi:10.1037/0096-1523.25.4.1076

Bloesch, E. K., Davoli, C. C., Roth, N., Brockmole, J., & Abrams, R. A. (2012). Watch this! Observed tool-use affects perceived distance. *Psychonomic Bulletin & Review.* doi:10.3758/s13423-011-0200-z

Brascamp, J. W., Blake, R., & Kristjánsson, Á. (2011). Deciding where to attend: Priming of pop-out drives target selection. *Journal of Experimental Psychology. Human Perception and Performance, 37,* 1700–1707. doi:10.1037/a0025636

Buttaccio, D. R., & Hahn, S. (2011). The influence of action on visual search: Behavioral response toward stimuli modifies the selection process. *Attention, Perception, & Psychophysics, 73,* 1453–1466. doi:10.3758/s13414-011-0121-y

Davoli, C. C., Brockmole, J. R., & Witt, J. K. (2012). Compressing percieved distance with remote tool-use: Real, imagined, and remembered. *Journal of Experimental Psychology: Human Perception and Performance, 38,* 80–89. doi:10.1037/a0024981

Deubel, H., & Schneider, W. X. (1996). Saccade target selection and object recognition: Evidence for a common attentional mechanism. *Vision Research, 36,* 1827–1837. doi:10.1016/0042-6989(95)00294-4

Fox, E. (1995a). Negative priming from ignored distractors in visual selection: A review. *Psychonomic Bulletin & Review, 2,* 145–173. doi:10.3758/BF03210958

Fox, E. (1995b). Pre-cueing target location reduces interference but not negative priming from visual distractors. *Quarterly Journal of Experimental Psychology, 48,* 26–40. doi:10.1080/14640749508401373

Gozli, D. G., West, G. L., & Pratt, J. (2012). Hand position alters vision by biasing through different visual pathways. *Cognition, 124,* 244–250. doi:10.1016/j.cognition.2012.04.008

Hommel, B. (1998). Event files: Evidence for automatic integration of stimulus-response episodes. *Visual Cognition, 5,* 183–216. doi:10.1080/713756773

Hommel, B. (2004). Event files: Feature binding in and across perception and action. *Trends in Cognitive Sciences, 8,* 494–500. doi:10.1016/j.tics.2004.08.007

Huang, L., Holcombe, A. O., & Pashler, H. (2004). Repetition priming in visual search: Episodic retrieval, not feature priming. *Memory & Cognition, 32,* 12–20. doi:10.3758/BF03195816

Kristjánsson, Á. (2006). Simultaneous priming along multiple dimensions in visual search task. *Vision Research, 46,* 2554–2570. doi:10.1016/j.visres.2006.01.015

Kristjánsson, Á., & Campana, G. (2010). Where perception meets memory: A review of repetition priming in visual search tasks. *Attention, Perception, & Psychophysics, 72,* 5–18. doi:10.3758/APP.72.1.5

Kristjánsson, Á., Saevarsson, S., & Driver, J. (2013). The boundary conditions of priming of visual search: From passive viewing through task-relevant working memory load. *Psychonomic Bulletin & Review, 20,* 514–521. doi:10.3758/s13423-013-0375-6

Makovski, T., Jiang, Y. V., & Swallow, K. M. (2012). How do observer's responses affect visual long-term memory? *Journal of Experimental Psychology: Learning, Memory, and Cognition, 39,* 1097–1105. doi:10.1037/a0030908

Maljkovic, V., & Nakayama, K. (1994). Priming of pop-out: I. Role of features. *Memory & Cognition, 22,* 657–672. doi:10.3758/BF03209251

May, C. P., Kane, M. J., & Hasher, L. (1995). Determinants of negative priming. *Psychological Bulletin, 118,* 35–54. doi:10.1037/0033-2909.118.1.35

Olivers, C. N. L., Peters, J., Houtkamp, R., & Roelfsema, P. R. (2011). Different states in visual working memory: When it guides attention and when it does not. *Trends in Cognitive Sciences, 7,* 327–334. doi:10.1016/j.tics.2011.05.004

Soto, D., Heinke, D., Humphreys, G., & Blanco, M. (2005). Early, involuntary top-down guidance of attention from working memory. *Journal of Experimental Psychology. Human Perception and Performance, 31,* 248–261. doi:10.1037/0096-1523.31.2.248

Symes, E., Tucker, M., Ellis, R., Vainio, L., & Ottoboni, G. (2008). Grasp preparation improves change detection for congruent objects. *Journal of Experimental Psychology: Human Perception and Performance, 34,* 854–871. doi:10.1037/0096-1523.34.4.854

Witt, J. K. (2011). Action's effect on perception. *Current Directions in Psychological Science, 20,* 201–206. doi:10.1177/0963721411408770

Witt, J. K., Proffitt, D. R., & Epstein, W. (2005). Tool use affects perceived distance but only when you intend to use it. *Journal of Experimental Psychology: Human Perception and Performance, 31,* 880–888. doi:10.1068/p5090

Woodworth, R. S. (1899). The accuracy of voluntary movement. *Psychological Review, 3,* 1–119.

Wykowska, A., Schubö, A., & Hommel, B. (2009). How you move is what you see: Action planning biases selection in visual search. *Journal of Experimental Psychology. Human Perception and Performance, 35,* 1755–1769. doi:10.1037/a0016798

Yashar, A., Makovski, T., & Lamy, D. (2013). The role of motor response in implicit encoding: Evidence from intertrial priming in pop-out search. *Vision Research, 93,* 80–87.