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ORIGINAL ARTICLE

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The effect of previous trial type on inhibition of return

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Abstract Inhibition of return (IOR) refers to the finding that targets appearing at previously cued locations are more slowly responded to than targets appearing at previously uncued locations when a relatively long temporal interval occurs between the cue and target. This experiment was conducted to determine whether the magnitude of IOR is influenced by the type of preceding trial (cued or uncued) and/or the location of the cue/target on the previous trial. Although no effect of cue/target location is observed, there was a marked effect of previous trial type, as IOR was greater following an uncued trial relative to a cued trial. This effect was attributable to differences in the response time as a function of previous trial type: specifically, participants were faster to respond to cued and uncued trials when the previous trial type was identical.

Introduction

It has been repeatedly demonstrated that when attention is oriented to a particular location in the visual field, the detection of target stimuli at that location is initially facilitated relative to other locations (e.g., Posner & Cohen, 1984). Once attention has been disengaged from that location, however, individuals are slower to detect targets at the previously attended location relative to other locations in the visual field. This biphasic pattern of response time has been termed inhibition of return (IOR) and was originally reported by Posner and Cohen (1984). IOR has often been thought of as a mechanism that aids visual search by preventing attention from returning to previously attended locations (Klein, 1988).

Since Posner and Cohen's (1984) initial report, numerous researchers have examined the manner in which various manipulations affect IOR. For example, IOR has been examined within the context of visual search (e.g., Gilchrist & Harvey, 2000; Horowitz & Wolfe, 1998, 2001, 2003, Klein, 1988; Klein & MacInnes, 1999), under conditions of divided attention (e.g., Castel, Pratt, & Craik, 2003), within elderly and patient populations (e.g., Castel, Chasteen, Scialfa, & Pratt, 2003; Larrison-Faucher, Briand, & Sereno, 2002; Moritz & von Muhlenen, 2005), following the presentation of multiple sequential or simultaneous cues (e.g., Dodd, Castel, & Pratt, 2003; Klein, Christie, & Morris, 2005; Posner & Cohen, 1984, Snyder & Kingstone, 2001; Wright & Richard, 1996), with discrimination tasks (e.g., Lupianez, Milan, Tornay, Madrid, & Tudela, 1997; Pratt, 1995; Pratt & Abrams, 1999), with both endogenous and exogenous shifts of attention (e.g., Rafal, Calabresi, Brennan, & Sciolto, 1989), and with saccadic and motor response (e.g., Taylor & Klein, 2000). In virtually all of these studies, IOR is measured in the manner that was originally employed by Posner and Cohen (1984): by calculating the difference between the mean response times to detect targets at cued and uncued locations. While this is the standard manner of measuring the effect, examining IOR in this way leads one to ignore other potential important influences on the inhibitory effect: specifically, the influence of the previous trial type on current trial performance. In this study, we examine whether the magnitude of IOR on a current target detection trial is influenced by the type of trial(s) that preceded it.

To date, the only investigation of previous trial type on IOR was reported by Maylor and Hockey (1987), who examined sequence effects in cue–target and target–target detection tasks. In their Experiment 1, participants performed a target detection task in which the same location was cued (cue run length) for 1, 5, or 30 consecutive trials prior to the presentation of a target at

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either the cued or uncued location. This was compared to a random cue–target detection task in which there was no systematic manipulation of where the cue would appear on each trial. Facilitation was observed in all conditions, though the magnitude of facilitation decreased as the cue run length increased (not significantly so, however). The magnitude of IOR, although unaffected by cue run length, was also present and equivalent in every cue condition. Interestingly, however, the magnitude of IOR was affected by the location of the target on the previous trial: the effect was greater when the target appeared in the same location as both the cue and previous target, relative to when the target appeared in the same location as the cue only. This finding did not replicate in two subsequent experiments in which a target–target paradigm was used and IOR actually decreased with repetition, indicating that the initial increase in IOR was attributable to target location remaining random even when a single location was consecutively cued. That random events (e.g., cue and target) are required to observe sequence effects opens up the possibility that previous trial type will influence current trial performance in a standard IOR task in which both the cue and target occur at random.

Beyond the Maylor and Hockey (1987) study, there are two strong reasons to believe that performance in a target detection task may change on a trial-to-trial basis. First, in choice reaction time (RT) tasks, it has been repeatedly demonstrated that the performance on a current trial is influenced by the previous trial type (e.g., Bertelson, 1961; Fecteau, Au, Armstrong, & Munoz, 2004; Kirby, 1976; Soetens, 1998). In these tasks, participants are required to respond to a target in either the left or right visual field via a saccadic or manual response. When a previous trial is taken into consideration, there are two different trial types that may follow: repetition (requiring the same response as the previous trial) and alternation (requiring a different response from the previous trial). In comparing these two different trial types, an alternation advantage arises such that participants are faster to respond when two consecutive trials require a different response rather than an identical response. It has been posited that this alternation advantage is attributable to participant expectations (Kirby, 1976; Soetens, 1998; though see Fecteau et al., 2004). Although the majority of IOR tasks require a detection key press rather than a choice key press, there is reason to believe that this alternation advantage may influence the performance in a standard target detection task. Maylor and Hockey (1985) have suggested that the magnitude of IOR may change on a trial-by-trial basis as a function of the "ranges and probabilities of (response-stimulus) intervals or SOAs used" (p. 786), as probability may influence participant expectation (though it is important to note that these researchers also outline arguments to the contrary). To this end, Maylor and Hockey (1985) have demonstrated that IOR can be generated in a target–target detection, a finding consistent with the notion that the influence of IOR may extend across trials, and that the IOR effect is not dependent on the presence of an uninformative cue. That the response type in the Maylor and Hockey experiment was simple key press and not choice key press suggests that the effect of previous trial type in a target detection task is not limited to paradigms in which a choice response is required. Moreover, Fecteau et al. have argued that the alternation advantage may actually be attributable to IOR as the effect is very similar to the time course and magnitude of IOR in target–target paradigms (e.g. Maylor & Hockey, 1985). If the alternation advantage is influenced by IOR (or alternatively, if the two effects are identical), then this leaves open the possibility that the alternation advantage will also be observed in simple target detection tasks.

Second, outside of IOR and target detection tasks, there are known influences of prior trials on current trials in other attentional domains. One of the best examples of such an effect would be negative priming, the finding that a target stimulus is more slowly responded to on a current trial (probe trial) when that same stimulus was to be ignored on a previous trial (prime trial: e.g., Dalrymple-Alford & Budayr, 1966; Lowe, 1979; Neill, 1977; Tipper, 1985, 2001 for a review). Generally, negative priming is accounted for in terms of inhibitory processes, wherein the to-be-ignored item is inhibited on the prime trial which makes that same item more difficult to process on the probe trial. Other accounts of the effect exist, however, such as Neill's (Neill & Mathis, 1998; Neill & Valdes, 1992) episodic retrieval account of negative priming. Adapted from Logan's (1988) instance theory of automaticity—which states that individuals regularly, and automatically, retrieve information from memory to facilitate performance on a current task—Neill and colleagues suggest that individuals are highly likely to recall the most recently encountered episode, that being the previous trial. When this memory check process elicits a do-not-respond tag on an item that was encountered during the prime trial, it conflicts with the instruction to respond to this same item on the probe trial. Negative priming reflects the time spent resolving this conflict (Neil & Mathis, 1998; MacLeod, Dodd, Sheard, Wilson, & Bibi, 2003). Although Neill's account of negative priming has not been applied to target detection tasks, it is easy to see how memory retrieval would influence detection performance. Participants should be faster to respond to targets when either the trial type (cued or uncued) or cue/target location (left or right) is repeated relative to when they are not.

Although neither the alternation advantage nor the instance theory of automaticity have been applied to IOR in simple detection tasks, it is worthwhile to note that the two accounts would predict differences in the magnitude of IOR on a current trial as a function of previous trial type. If an alternation advantage influenced IOR, then it would be expected that IOR would be decreased in magnitude when the trial type (cued or uncued) or the cue/target location (left or right) alter-

nates relative to when it repeats. Using the negative priming terminology introduced above, if the prime trial is an uncued trial, participants will be expecting a cued trial on the probe trial. The increase in response speed associated with the expected alternation should offset the inhibitory effect associated with the target appearing at the cued location. Similarly, if the prime trial is a cued trial and the probe trial is also a cued trial, an increase in the magnitude of IOR might be expected on the latter trial as participants will be slowed by both IOR and the potential cost associated with a repeated trial. If, on the other hand, some form of automatic memory check influences IOR, then the opposite pattern of results should be expected. Again, using the examples and terminology from above, if the prime trial is an uncued trial and the probe trial is a cued trial, an increase in the magnitude of IOR would be expected. This is because the individual is slowed by both the IOR associated with the cued trial, as well as the conflict in trial type between the prime and probe trials. When both the prime and probe trials are cued, however, the magnitude of IOR should decrease, as the IOR effect should be offset by the benefits associated with repeating a trial (e.g., no conflict to be resolved). Of course, there also exists a possibility that the previous trial type will have no effect on the magnitude of IOR on a current trial, but given the results of Maylor and Hockey (1987), we consider this possibility unlikely.

The present study was conducted to determine whether the magnitude of IOR changes on a trial-by-trial basis as a function of the previous trial type and if so, whether the influence of previous trials is more consistent with the alternation advantage or some form of automatic memory check. The task was simple target detection in which a target appeared at one of two locations following a nonpredictive cue. IOR, however, was analyzed as a function of the type of preceding trial(s).

Methods

Participants

Forty-eight undergraduate students from the University of Toronto volunteered to participate in the experiment, and received course credit for their participation. All participants had normal or corrected-to-normal vision and were naïve about the purpose of the experiment, which took place in a single 1-h session.

Apparatus and procedure

The experiment was conducted on a Pentium computer with a VGA monitor in a dimly lit, sound attenuated testing room. Participants were seated 44 cm from the front of the computer monitor with their heads held steady by a chin and headrest. A keyboard was placed directly in front of the participant and they made responses using the space bar on the keyboard.

At the beginning of each trial, a central fixation point (white, 0.2° in diameter) and two white outline square placeholders (each subtending 1° with one placeholder positioned 5° to the left of fixation and the other placeholder placed 5° to the right of fixation) were presented on the computer monitor with a black background.

Participants were instructed to fixate on the central fixation point, and to not make any eye movements. After a period of 800 ms, one of the placeholders was cued for a period of 200 ms by enlarging and illuminating its outline. The cued location was not predictive of the upcoming target location and was equally likely to occur at the left or right placeholder. Following the offset of the cue, there was a 200-ms delay prior to the participants being cued back to fixation by enlarging and illuminating the fixation cue. The fixation cue remained onscreen for 200 ms and was followed by an additional 200-ms delay, at the end of which a target (a white circle) appeared inside one of the two placeholders. The target was equally likely to appear inside either of the placeholders. Participants were instructed to press the spacebar as soon as they detected the target, and were told to respond as quickly and accurately as possible. The next trial began 1,000 ms after each response.

To reduce anticipatory responses, catch trials in which the target did not appear were also included and participants were told not to respond if the target did not appear. Incorrect responses on catch trials (and responses with RTs shorter than 100 ms and responses with RTs longer than 1,000 ms) were considered errors, and a short error tone was presented if any of these occurred.

Design

The experiment consisted of 200 trials, with 160 test trials and 40 catch trials. The target appeared at the cued location on 80 trials and at the uncued location on 80 trials. Short breaks were given after every 100 trials.

Results

Errors occurred on less than 1.7% of all trials and these trials were excluded from the analyses. Mean RTs for targets appearing at each location as a function of cue condition and previous trial type, as well as IOR effects for each cue condition, are presented in Fig. 1. Moreover, mean RTs for targets appearing at each location as a function of cue condition and previous two trial types, as well as IOR effects for each cue condition, are presented in Fig. 2.

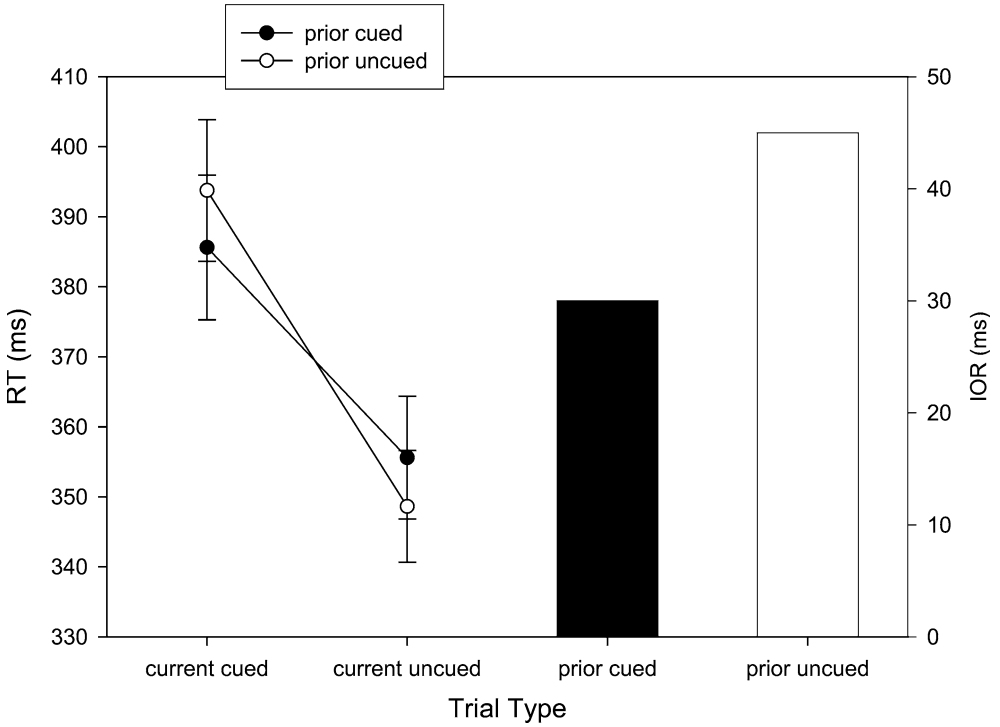

Fig. 1 Mean RTs (ms) for cued/uncued trials and IOR effects (calculated by subtracting the mean RT for targets appearing at uncued locations from the mean RT for targets appearing at cued locations) as a function of the previous trial type (cued or uncued)

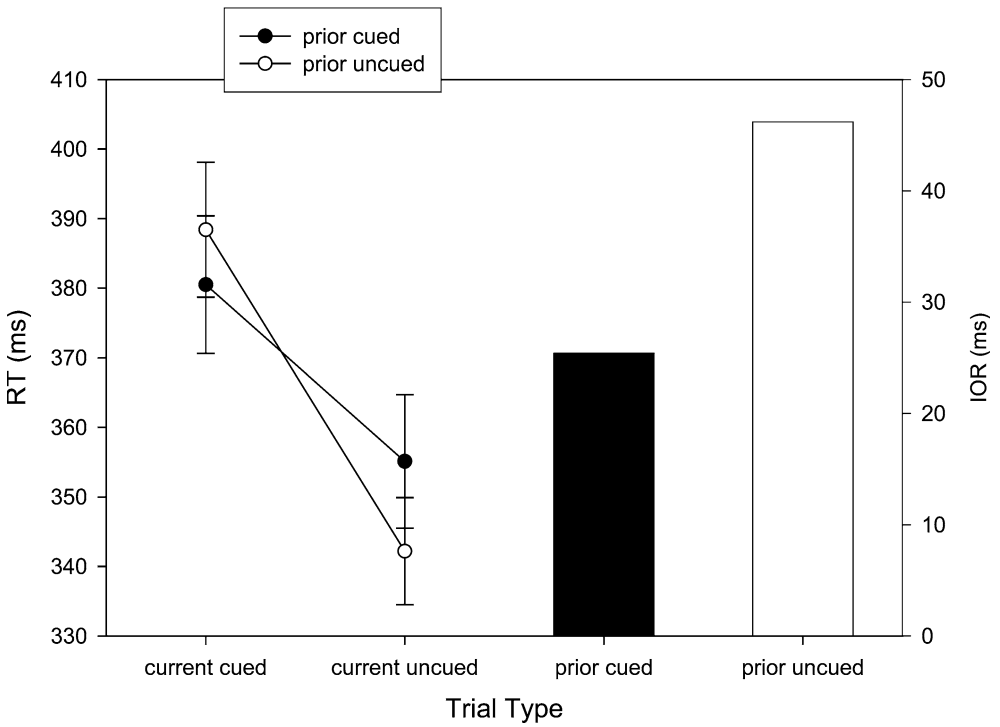

Fig. 2 Mean RTs (ms) for cued/uncued trials and IOR effects (calculated by subtracting the mean RT for targets appearing at uncued locations from the mean RT for targets appearing at cued locations) as a function of the previous two trial types (both cued or both uncued)

To determine whether there was an effect of previous trial type on the magnitude of IOR, a 2 (previous trial type: cued or uncued) × 2 (current trial type: cued or uncued) × 2 (target location: same or different than previous trial) analysis of variance (ANOVA) was carried out. There was a main effect of current trial type, $F(1, 47) = 78.24$, MSE = 1,823.13, $P < 0.001$, representing the standard IOR effect, and a main effect of target location, $F(1, 47) = 10.73$, MSE = 622.05, $P < 0.01$, indicating that participants were faster to respond to targets when they appeared in the same location as they had on the previous trial. Critically, there was a significant interaction between previous trial type and current trial type, $F(1, 47) = 12.49$, MSE = 459.65, $P < 0.001$, dem-

onstrating that participants were faster to respond on a current trial when the trial type matched that on the previous trial. An examination of Fig. 1 elucidates this trend. The magnitude of IOR was greater when the previous trial was uncued (45 ms) relative to when it was cued (30 ms). This increase was attributable to differences in RT on current trials as a function of previous trials. Participants were faster to respond to cued trials when the previous trial was cued relative to when it was uncued, and faster to respond to uncued trials when the previous trial was uncued relative to when it was cued. No other main effects or interactions were significant.

To determine the influence of encountering two identical trial types prior to the current trial, a 2 (previous trial types: both cued or both uncued) × 2 (current trial type: cued or uncued) ANOVA was also conducted[1]. There was a significant main effect of current trial type, $F(1, 47) = 75.83$, $MSE = 810.43$, $P < 0.001$, representing the standard IOR effect, but no main effect of previous trial type, $F(1, 47) < 1$. Critically, there was an interaction between previous trial type and current trial type, $F(1, 47) = 11.40$, $MSE = 454.02$, $P < 0.001$, as participants were faster to respond when the current trial type matched the two previous trials relative to when the current trial type was different than the previous two trials. An examination of Fig. 2 reveals that the magnitude of IOR increased following two uncued trials (46 ms) relative to following two cued trials (26 ms). As in the previous analysis, this increase was attributable to differences in the RT on current trials as a function of previous trials. Participants were faster to respond to cued trials when the previous two trials were cued relative to when they were uncued, and were faster to respond to uncued trials when the previous two trials were uncued relative to when they were cued. Moreover, while not significant, the difference in the magnitude of IOR as a function of previous trial type(s) was greater when the two previous trials were both cued or both uncued (20 ms) relative to when only one previous trial was cued or uncued (15 ms).

General discussion

The present experiment was conducted to determine whether a previous trial type influences the magnitude of IOR on a current trial. We were particularly interested in whether one of two contrasting theories (alternation advantage vs. instance theory) might influence target detection performance. The results demonstrate that IOR is indeed influenced by the type of preceding trial. Specifically, the magnitude of IOR was greater when the target appeared at an uncued location on a previous trial relative to when the target appeared at a cued location. This increase was attributable to differences in RT as a function of previous trial type. Participants were faster to respond to cued trials when the previous trial was cued relative to when it was uncued, and faster to respond to uncued trials when the previous trial was uncued relative to when it was cued.

The present results are consistent with Logan's (1988) instance theory of automaticity. Logan has suggested that when performing a task, participants are highly likely to automatically—and unintentionally—retrieve information from memory to facilitate current task performance. Within the context of negative priming, Neill and colleagues (Neill & Mathis, 1998; Neill & Valdes, 1992) have suggested that individuals are highly likely to recall the most recently encountered episode, that being the previous trial. Thus, when the previous trial type is consistent with the current trial type, performance should be facilitated, whereas when the previous and current trial types differ, performance is slowed as participants must first overcome the conflict between the two trials. This can account for why the magnitude of IOR increased in the present experiment when the previous trial was uncued: participants are then slower to respond to cued trials due to both the effects of IOR, and the conflict between the two trial types. Moreover, this would account for the decrease in RT when the target appears at the same location on a current trial that it had on a previous trial. To the best of our knowledge, this is the first demonstration that some form of automatic memory check may influence the magnitude of IOR on a trial-by-trial basis. It is worth noting, however, that Tipper and colleagues (e.g., Kessler & Tipper, 2004; Tipper, Grison, & Kessler, 2003) have argued that their demonstrations of long term IOR may reflect the encoding into memory of inhibition that is reinstated at a later time. Moreover, Castel et al. (2003) have argued that IOR may be attributable to some form of spatial working memory. Thus, the present results provide a further demonstration of a possible role of memory in IOR.

Although the present results are consistent with Logan's (1988) instance theory of automaticity, they are inconsistent with what would have been expected had an alternation advantage influenced IOR. There are two possible reasons why an alternation advantage may not have occurred in the present experiment. First, the present task was a simple target detection task that did not require a choice response. Generally, alternation advantages are observed in tasks which require one of two response types on a given trial (left or right key press or left or right saccade). We had reasoned that an alternation advantage still may be observed in the present task given the potential role of oculomotor programming in IOR—and given the results of Maylor and Hockey (1985)—but this was not the case. Second, Fecteau et al. (2004) have argued that the alternation advantage does not reflect expectations, but rather the effect originates from sensory processing. Indeed, Fecteau et al. have argued that the alternation advantage may actually be attributable to IOR as the effect is very

[1]Given the lower proportion of trials that were followed by the two previous identical trial types, we were unable to include target location as a variable in this analysis

similar to the time course and magnitude of IOR in target–target paradigms (e.g., Maylor & Hockey, 1985). If the two effects are identical, then the effect of the alternation advantage in a cue–target study might be limited to only a single trial rather than across trials (with the cue and target representing the two relevant events as opposed to the two separate target events in a choice RT task). In any case, we found no evidence of an alternation advantage influencing IOR across trials in the present study.

It is interesting to note that while the present results are consistent with Maylor and Hockey's (1987) finding that the previous trial can influence IOR on a current trial, we did not replicate their finding that IOR was greater when the cue and target appear on a current trial at the same location as the target on the previous trial. This was likely due to methodological differences between the two studies given that Maylor and Hockey manipulated the cue location on every trial to investigate sequence effects (with a single location being cued on up to 30 consecutive trials) whereas in the present study, the cue and target location were randomized on each trial (indeed, Experiments 2 and 3 of Maylor and Hockey also demonstrate how total randomization can alter the pattern of result they obtained in Experiment 1). Despite our failure to replicate the Maylor and Hockey finding, the present results (in combination with those of Maylor and Hockey) are important in that they provide a more complete understanding of the influence of a previous trial on IOR on a current trial.

The present results also have important ramifications for current and future investigations of IOR. As was previously mentioned, the standard manner of measuring IOR is to compare the mean RT to detect targets at cued locations with the mean RT to detect targets at uncued locations. Collapsing data in this manner ignores the potential influence of the trial-by-trial effects that we report here. Moreover, the present results suggest that the magnitude of IOR will change as the proportion of cued trials in an experiment increases. Although the vast majority of IOR experiments employ an equal number of cued and uncued trials, some researchers opt to use either a higher or lower proportion of cued trials relative to uncued trials in their experiments (e.g., Danziger & Kingstone, 1999), or to present targets at locations where a cue never occurs (e.g., at fixation, Posner & Cohen, 1984). These manipulations can either increase or decrease the number of repetition trials which will in turn lead to changes in the magnitude of IOR. These issues will need to be taken into consideration when future experiments are designed.

In summary, the present experiment demonstrates that the magnitude of IOR on a current trial is influenced by the type of trial that preceded it. Participants are faster to respond to targets on cued trials when they were preceded by a cued trial relative to an uncued trial. The opposite is true of uncued trials. These results are consistent with Logan's (1988) instance theory of automaticity in which individuals are said to retrieve information from memory to facilitate performance on a current task. These results are the first demonstration that previous trial type influences IOR and provides further evidence that some form of memory influences IOR.

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