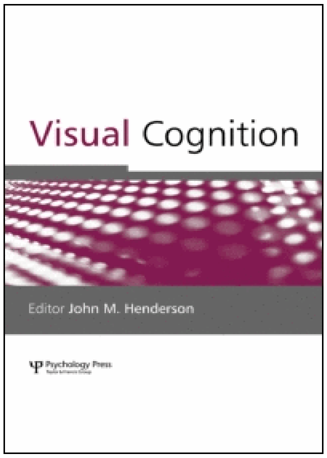

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Effects of stimulus-onset asynchrony and display duration on implicit and explicit measures of attentional capture by a surprising singleton

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Effects of stimulus–onset asynchrony and display duration on implicit and explicit measures of attentional capture by a surprising singleton

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The surprise-attention hypothesis, stating that expectancy-discrepant stimuli can capture attention, is tested in two visual search experiments with accuracy as the dependent variable. The expectancy-discrepant stimulus was the unannounced presentation of a location precue in a new colour. As the precue was presented at the location of a nontarget, attentional capture was expected to register in a performance decrement in the critical trial. Experiment 1 revealed that attentional effects are absent after 100 ms but present after 400 ms. Experiment 2 showed that this effect is due partly to presentation duration. These results indicate that surprise capture has a late onset and requires a stable representation. In addition, the results indicate that traditional measures of attention capture and verbal reports of awareness can dissociate.

According to the surprise-attention hypothesis, events that deviate from expectation attract attention, and thus receive elaborate processing (e.g., Darwin, 1872; Horstmann, 2002, 2005, 2006; Meyer, 1988; Meyer, Niepel, Rudolph, & Schützwohl, 1991; Prinz, 1983, 1990; Schützwohl, 1998; Selz, 1922; Wilcocks, 1928). The detection of an expectancy discrepancy can be intentional as when an observer purposefully tests a hypothesis or prediction, with the expected outcome represented consciously in his or her mind (e.g., Horstmann & Schützwohl, 1998). In addition to this *explicit* hypothesis testing, a discrepancy is often detected between an event and an *implicit* expectation (Meyer, 1988; see also Selz, 1922, and Wilcocks, 1928), that is, when an observer does not intentionally test hypotheses, and may not even be aware of his or her expectancies (see, e.g., Horstmann, 2002; Meyer et al., 1991; Schützwohl, 1998). To account for this observation, the surprise-attention hypothesis assumes that implicit expectancies are continuously

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generated and tested without intent and conscious awareness (see also Neisser, 1976, 1979; Prinz, 1990; Rumelhart, 1984; Rumelhart & Ortony, 1977).

This hypothesis was tested most directly by Horstmann (2002; see also Horstmann, 2005, 2006), based on a paradigm introduced by Gibson and Jiang (1998), where participants performed a serial search for targets defined by shape (H or U) among a number of distractor letters (for related evidence see Meyer et al., 1991; Niepel, Rudolph, Schützwohl, & Meyer, 1994; Schützwohl, 1998; Wilcocks, 1928). In one series of experiments, the letters appeared briefly on coloured patches. Accuracy was the dependent variable. Three types of trials were tested: precritical, critical, and postcritical. In precritical trials, all patches had the same colour within and between trials (e.g., red colour patches were presented in all precritical trials at the positions of all letters). The task was relatively demanding, and the target was missed in many trials because presentation time was too brief to allow a serial scan of all letters and the position of the target letter was not singled out by a position cue.

In the critical trial, the colour patch behind the target letter was presented in a new colour (e.g., green). The participants were not informed about this change before it occurred. It was reasoned that if the new colour captured spatial attention to its position, the detection of the target letter at the same position would be improved. In line with this reasoning, performance in the critical trial was much better than in the precritical trials, but only if the colour patches preceded the letters by 400 ms (Horstmann, 2006, Exp. 1) or 500 ms (Horstmann, 2002, Exp. 1; 2006, Exp. 2), but not if the SOA was shorter than 300 ms (Horstmann, 2002, Exp. 2; 2006; Gibson & Jiang, 1998, Exp. 1). This time course was specific to the *unannounced* singleton presentation in the critical trial: When the singletons regularly appeared at the position of the target in the postcritical trials, it was nearly always correctly identified, but performance was hardly affected by SOA. In addition, Horstmann and Ansorge (2006) showed that with rare but expected (and thus unsurprising) singletons at the position of the target (target singleton) or at one of the distractors (distractor singleton), performance is also not strongly influenced by SOA. Converging evidence comes from experiments where set size (i.e., the number of distractors) was manipulated (Horstmann, 2002, Exp. 3; 2005). These experiments revealed an effect of set size on search time in the precritical trials, but a strong reduction of the set size effect in the critical and in the postcritical trials.

The performance benefit in the critical trial conforms with the surprise-attention hypothesis. It verifies that attention is shifted to the position of the new colour even in the absence of a corresponding attentional set (cf. Folk, Remington, & Johnston, 1992): Letter colour was irrelevant to the letter-search task, and in particular, did not discriminate between the target and the distractor letters in the precritical trials. Thus, the shift of attention in the critical trial cannot be attributed to a variant of contingent capture, where the attentional settings are made prior to the appearance of the stimulus, and where the stimulus quickly summons attention as a consequence of its fit to the attentional settings (Folk et al., 1992). In addition, the time course of the benefit suggests that the shift of attention occurred with a time lag of about 300 ms, as compared to an intended and preplanned shift of attention. This fosters the conclusion that the mechanisms for surprise capture and contingent capture are different.

THE PRESENT EXPERIMENTS

As in previous experiments, we presented a colour singleton in the critical trial after a number of precritical no-singleton trials. In the present experiments, however, we presented the new colour at the position of a distractor (distractor singleton; see also Gibson & Jiang, 1998, Exp. 2) rather than at the position of the target, as in prior experiments (target singleton; e.g., Horstmann, 2002). The hallmark of attention capture by a distractor singleton is a performance decrement: The new colour should misguide attention to the position of the distractor, thereby lowering the chances of perceiving the briefly presented target letter relative to the precritical trials without a singleton.

The presentation of a distractor singleton enabled us to decide between two hypotheses on the causes of the specific time course of surprise capture. We have previously assumed that the time course of surprise capture is due to a relatively late onset of the attention shift. Another possibility, however, is that the surprise singleton captures attention as quickly as an expected singleton. The reason why beneficial effects of a surprise target-singleton accrue only with a delay may be that the central processing of the expectancy-discrepant feature (the colour) is given priority, which interferes with the processing of the identities of the letters (cf. Gibson & Jiang, 1998).

The delayed-onset account and the interference account make similar predictions for surprise target-singletons, but different predictions for surprise distractor-singletons. On the delayed-onset account, the time course of costs induced by a surprise distractor-singleton should be a mirror image of the time course of benefits with a surprise target-singleton. That is, the costs should be low with a short SOA (e.g., 100 ms) but high with a long SOA (e.g., 400 ms). In contrast, the interference account predicts interference at short SOAs, with dissipating interference as SOA increases. That is, performance costs would be strongest with short SOAs, and decrease as the SOA increases.[1]

A second aim of the present study was to obtain explicit self-report measures of awareness for the unannounced singleton, in addition to the implicit measure of changes in search performance. To that aim, participants were asked whether they had noticed something different immediately after the first unannounced presentation of the colour singleton. Explicit and implicit measures of attention for an unannounced singleton have been assessed before by Gibson and Peterson (2001), who found neither attention capture nor awareness with a 0 ms SOA. This result suggests that implicit and explicit measures of attention are associated rather than dissociated. The present experiments were aimed to test whether the two measures of attention are still associated with longer display durations or larger SOAs.

Awareness is the main dependent variable in research on inattentional blindness (IB), which is revealed when observers are unable to report the presence of an unannounced stimulus (e.g., Mack & Rock, 1998). Mack and Rock, working with restricted viewing conditions (200 ms plus mask), found IB (20–75% of the participants) even when the critical stimulus was red in an otherwise black-and-white surround. In these experiments, an important factor for IB was whether the critical stimulus fell within the "zone of attention", which is roughly the spatial distance between the primary task stimulus and the critical stimulus. Most, Simons, Scholl, Jimenez, Clifford, and Chabris (2001), using much longer presentation durations (but also a more demanding task), found low IB rates (28%) for a red stimulus among black-and-white stimuli. According to Most et al. (2001), the most important factor for IB is the mismatch of the critical stimulus's features to the attentional set (see Folk et al., 1993), though a lack of salience may also contribute. As already indicated, Gibson and Peterson (2001) did find some IB (37%) with a colour singleton in a surprise paradigm. They assume that IB occurred because the task required participants to focus attention on the individual stimuli (focal attention), rather than on the display as a whole (diffuse attention), with focal attention preventing the computation of visual salience.

Very little is known about the temporal and causal relation between awareness and attention (see also, Gibson & Peterson, 2001). It is commonly assumed that attention supports awareness, which implies that attention leads and causes awareness in many instances. However, there is controversy over whether this general rule also holds for the awareness of a feature

[1] Another way to view the two hypotheses is in terms of spatial versus nonspatial interference. The delayed-onset account assumes spatial costs (i.e., costs that are proportional to the distance between the target and the singleton), whereas the interference account assumes nonspatial costs, which depend on the mere presence of the singleton and not on its position.

singleton. Some authors assume that the saliency of a singleton is computed prior to attention (e.g., Theeuwes, 1991, 1992; Treisman, 1988; Wolfe, 1994). Others hold that the computation of saliency requires attention (e.g., Gibson & Peterson, 2001; Mack & Rock, 1998). One might note, however, that both accounts share the assumption that focal attention is not necessary to detect a feature singleton. Thus, conscious singleton detection may temporally precede focal attention. Concerning the causal relationship, McCormick (1997) found an onset-cue to capture attention in the absence of awareness. This result suggests that awareness is no necessary condition for attentional capture. However, whether this finding extends to feature singletons is unknown.

Based on these considerations, we expected that awareness and attentional capture are able to dissociate. In particular, if the singleton can be detected prior to focal attention to the stimulus, awareness should have a distinct time course from the effects of an attentional shift, with an earlier onset of awareness.

The second experiment aimed at further clarifying the role of stimulus duration for the SOA effect. Previous experiments presented the letters on colour patches, which lead the letters by the specified SOA. Thus, the effects of SOA and of stimulus duration are confounded. Assuming that the SOA effect is indeed due to a delayed onset of the attention shift, there are two alternatives as to the causes of the delayed onset. First, it is possible that display duration per se is the critical variable. This could be the case, for example, because of temporal summation of activation for the triggering of the attentional shift. Second, SOA may be important independent of the stimulus duration, simply because the surprise response is very slow.

EXPERIMENT 1

Method

Participants. Thirty-two women and 16 men with a mean age of 23.5 ($SD = 4.8$) participated for a small monetary reward (€1).

Stimuli, apparatus, and procedure. ERTS (BeriSoft Cooperation), run on a microcomputer equipped with a 80486 CPU, was used for event scheduling and data registration. A 19-inch colour monitor was used for stimulus presentation and a standard keyboard served to register the responses. In each trial, following a fixation cross, eight coloured figure-of-eight placeholders ($0.7° \times 0.8°$ viewed from a distance of 57 cm; stroke strength = 4 pixels = 0.2°) appeared at equidistant positions of an imaginary circle with a radius of 3.4° (Figure 1). After a variable SOA of 100 or 400 ms, the placeholders were extinguished and replaced by eight solid-coloured

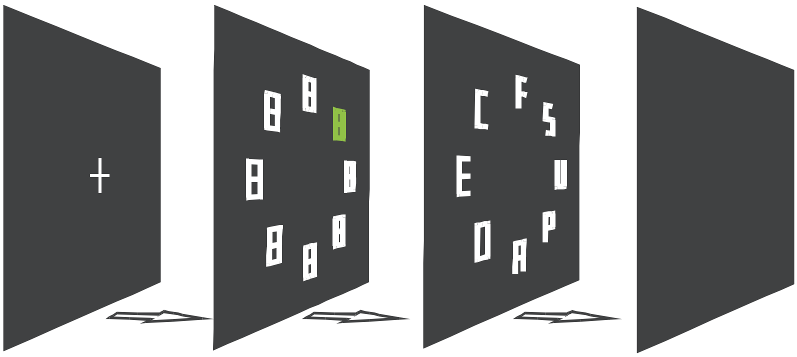

Figure 1. Display layout and trial structure in Experiment 1. The figure-of-eight placeholders were red or green (indicated here by white vs. grey). (Note: The figure is not drawn to scale.) To view this figure in colour, please see the online issue of the Journal.

letters ($0.7° \times 0.8°$) for a display duration of 86 ms. The letters were composed of horizontal and vertical line segments only and resembled the letters A, C, D, E, F, H, I, L, P, S, T, U, and M (which was, actually, an inverted U). With this composition of the letters, the target letters were not distinguishable from the nontarget letters on the basis of a single feature contrast (cf. Gibson & Jiang, 1998). This was intended to discourage any strategic tendency to search for a singleton, because in such a "singleton detection mode", any salient singleton can draw attention to its position (Bacon & Egeth, 1994). In each trial, one of the target letters (H, U, or M) was presented at a randomly chosen position, while the remaining seven positions were randomly filled with seven different letters. The three target letters were presented equally often in a random order.

The participants' task was to determine which of three possible target letters appeared, and to press a key accordingly. (The response keys were three adjacent keys in the lower row of a standard computer keyboard.) The instructions emphasized accuracy of response and explained that speed was only of secondary importance. Errors were immediately followed by error feedback, consisting of a short tone. Participants were instructed to fixate on the centre of the screen (indicated by the fixation cross at the beginning of the trial) throughout each trial. They were told that with the limited presentation time of the letters, doing so would be the best strategy to detect the target on as many trials as possible. They were informed that the task was difficult and that they would not see the target in many trials, in which case they should guess. In the precritical trials, which comprised 48 experimental trials preceded by 12 practice trials, all squares were of the same colour. They were followed by 48 trials where one square appeared in a new colour (not used in the precritical trials), whereas the remaining squares appeared in the old colour already used in the precritical trials. The differently coloured square always appeared in the position of a randomly chosen distractor. The first trial with a singleton square was the critical trial. The experiment flowed continuously from one segment to another, and the participants were not informed that one square would be presented in a different colour. For half of the participants in each condition, the singleton square was red and the remaining (nonsingleton) squares were green; for the other half, the colour assignment was reversed. The letters, the fixation cross, and the messages that appeared prior to and following the practice trials, had the same colour as the nonsingleton squares. SOA in the critical trial was varied between participants.

Immediately after the response in the critical trial, the experimenter asked whether the last trial was in any respect different from the preceding trials. If the participant answered in the negative, he or she was coded as having seen nothing. If the participants answered in the affirmative and immediately provided a description, the participant was coded in the following way: If the description was correct, i.e., the background frame preceding the letters was described as having appeared in a new colour, he or she was coded as having seen the change correctly; if it was only partly correct, like, for example, that the letter had a different colour, it was coded as partly correct; if it was wrong or irrelevant (e.g., that the last trial was easier or faster), the participant was coded as having seen nothing. If the participants reported a change but did not immediately describe it, the experimenter asked them what the change was. The answers were coded as outlined before.

Results

Figure 2 shows the performance in the letter search task (proportion of correct answers) for both SOA conditions. Proportion correct in the precritical trials reveal that the task was rather difficult. An ANOVA of mean accuracy data with SOA (100 vs. 400 ms) and trial type (precritical vs. postcritical) revealed a main effect for trial, $F(1, 47) = 17.2$, $p < .001$, and for SOA, $F(1, 47) = 20.5$, $p < .001$. Performance was slightly better in the postcritical than in the precritical trials (0.72 vs. 0.65), and it was better with a long rather than a short SOA (0.72 vs. 0.66). The interaction was not significant, $F < 1$.

The main analysis examined whether performance in the critical trial was more comparable to the preceding precritical trials or to the following postcritical trials. Because trial type is confounded with serial order of

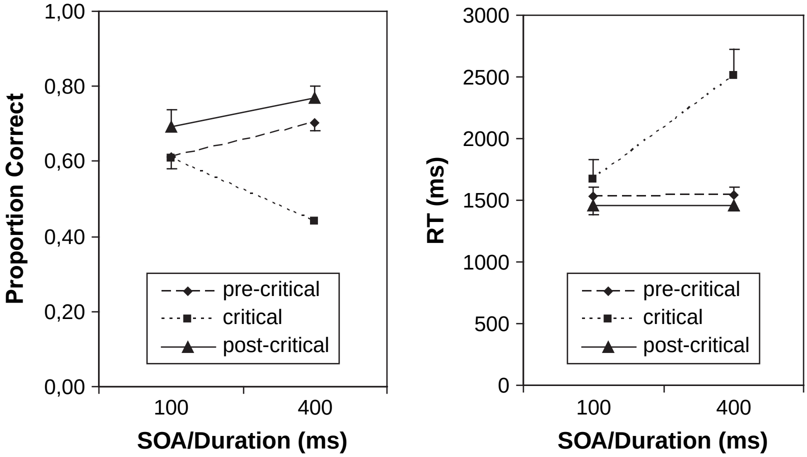

Figure 2. Proportion correct answers for the precritical trials, the critical trial, and the postcritical trial for the 100 ms and the 400 ms SOA conditions in Experiment 1. Error bars for the precritical and the postcritical trials show the standard error of the mean.

occurrence (e.g., the precritical trials always precede the critical trial), practice effects are possible. To account for them, proportion correct in the critical trial was predicted by means of linear regression, with trial number as the predictor (Horstmann, 2002; Gibson & Jiang, 1998). Separate linear regressions were computed for each condition, and on the basis of both the performance in the precritical trials and in the postcritical trials (Table 1). Because SOA proved to have an effect on performance (see earlier), only trials with the same SOA as in the critical trial were used. Furthermore, a 95% confidence interval (CI) for the population proportion correct was computed on the basis of the actually obtained proportion correct in the critical trial (see Table 1). This analysis revealed that in the 100 ms SOA condition, both the proportion correct predicted from the precritical and the postcritical trials fell within the CI for the obtained performance in the critical trial. In contrast, with the 400 ms SOA, the CI for the critical trial included neither the proportion correct predicted from the precritical trials nor that from the postcritical trials.

We also analysed the response latencies as an indicator of distraction and as an implicit measure of surprise (response latencies of more than 4000 ms were excluded to reduce error variance which pertained to five participants, all but one in the 400 ms condition). An ANOVA using trial type (precritical, critical, postcritical) and SOA (100 vs. 400 ms) as independent variables rendered a main effect of trial type, $F(2, 82) = 31.15$, $p < .001$, of SOA, $F(1, 41) = 4.5$, $p < .05$, and a significant interaction, $F(2, 82) = 15.2$, $p < .001$ (Huynh-Feldt-corrected), revealing that response latencies did not differ

TABLE 1
Results from Experiments 1 and 2

		Precritical trial prediction			*Postcritical trial prediction*		
	Condition	*Regression*	*Predicted*	*CI critical*	*Predicted*	*Regression*	*Actual critical*
Exp. 1	100	$y = -0.0029x + 0.65$	.65	.41–.78	.56	$y = 0.0105x + 0.56$	61
	400	$y = 0.0002x + 0.70$	.70	.26–.64	.81	$y = 0.0033x + 0.81$	44
Exp. 2	100	$y = -0.0040x + 0.75$	.75	.39–.86	.79	$y = 0.0031x + 0.79$	67
	400	$y = 0.0006x + 0.79$	.79	.20–.68	.78	$y = 0.0013x + 0.78$	42

Performance was regressed on trial number, with the critical trial assumed to be trial 0 (i.e., the precritical trials had negative, and the postcritical trials positive trial numbers). Because performance in the noncritical trials was affected by condition, the ordinal number of the occurrence of the respective stimulus duration was used. In addition to the regression equation, predicted performance in the critical trial is given as well as the 95% confidence interval (CI) for the critical trial. The last column (actual critical) contains the actual performance in the critical trial.

between the two SOA conditions in the precritical (1540 ms) and the postcritical trials (1456 ms), $ts(41) < 1$, but that RTs in the critical trial were much longer with a 400 ms than with a 100 ms SOA (1668 ms vs. 2512 ms), $t(41) = 3.2$, $p < .01$. Thus, distraction in the critical trial, as indicated by the RT increase, was stronger with a 400 ms SOA than with a 100 ms SOA, replicating the accuracy results.

The participants were interviewed immediately after the critical trial as to whether they had noticed a change in the display, and asked to specify it if indeed they had noticed a change. Most of the participants noticed the colour change. (All participants who reported a change described it correctly.) Noticers were somewhat more frequent in the 400 ms condition (88%) than in the 100 ms condition (73%), but the difference was not significant, $\chi^2(1; N = 48) = 1.6$, $p = .21$.

Discussion

A singleton presented for the first time without prior announcement resulted in a performance decrement when presented at the position of a distractor only if the SOA between singleton onset and letters onset was 400 ms, but not if the SOA was only 100 ms. This result is conceptually analogous to the results from previous experiments that showed performance benefits with a singleton presented at the target position, and reveals that the time course of costs with a distractor singleton is qualitatively similar to the time course of benefits with a target singleton.

A performance decrement with a distractor singleton relative to the no-singleton condition in the precritical trials is predicted by the hypothesis that the singleton in the critical trial captures spatial attention (e.g., Theeuwes, 1992, 1994), because if attention is shifted to a location different from the target, this should further reduce the chance of identifying the briefly presented target. By analogy, the fact that an SOA of 100 ms was not sufficient to yield performance costs suggests that the singleton did not capture attention, or at least, did not capture attention fast enough to disturb the letter searching task. These possibilities are further explored in the following experiment.

The present results support the delayed-onset account that shifts of attention to unannounced singletons are delayed in comparison to expected items. In turn, the results are so far incompatible with the interference account that explains the time course of benefits with a surprise target-singleton with the assumption that the processing of the singleton feature itself interferes with the processing of the target at the same spatial position. According to this account, one would also have expected a strongly reduced performance in the present experiment with a 100 ms SOA. In contrast, as predicted by the delayed-onset hypothesis, performance was not significantly altered with a short SOA, but only with a longer SOA.

We also analysed response latencies as an indirect indicator of surprise and interference induced by the colour change in the critical trial. According to this analysis, the singleton in the critical trial induced little interference in the 100 ms condition, but sizable interference in the 400 ms condition. This result supplements the accuracy data in suggesting that little attention was deployed to the singleton in the 100 ms SOA condition.

Reports of awareness were relatively frequent in the present experiment: About 80% of the participants reported to have seen the change and were also able to describe it correctly. There was only a small and nonsignificant trend towards lower awareness rates in the 100 ms than in the 400 ms condition. This result indicates that implicit and explicit measurements of attention in the present experiments can dissociate to some extent. At least, a shift of spatial attention to the unannounced singleton does not seem to be a prerequisite for awareness.

Because in the present experiment, the premask (figure-of-eight) display was presented until the letters appeared, it remains an open question which of two variables ultimately cause the delayed onset: elapsed time or stimulus duration. The following experiments were conducted to eliminate the confound between stimulus duration and SOA.

EXPERIMENT 2

Experiment 2 eliminated the confound of SOA and display duration by holding SOA constant while varying display duration: Display duration was either 100 ms or 400 ms, and SOA was fixed at 500 ms. If delayed onset of attention capture in Experiment 1 was due to the fact that, at the 400 ms SOA, more time had elapsed since the onset of the stimuli only, then evidence for attentional capture should be present in both conditions of Experiment 2. In turn, if differences between the stimulus duration in the 100 and 400 ms SOA conditions were responsible for the finding that attention capture only occurred in the latter, then performance decrements in the present experiment should be restricted to the 400 ms display duration condition.

Method

Participants. Twenty-four persons, 16 women and 8 men with a mean age of 24.6 ($SD = 4.5$) participated voluntarily for a small monetary reward (€1).

Apparatus, stimuli, and procedure. These were the same as in Experiment 1 except that the SOA was always 500 ms and the stimulus duration (i.e., figure-of-eight placeholder duration) was either 100 ms or 400 ms. In the interstimulus interval between the figure-of-eight placeholder and the letters, the screen was empty.

Results

Figure 3 shows the means for the performance in the critical trials with stimulus durations of 100 and 400 ms, and the corresponding means for trials of the same display durations in the precritical and the postcritical trials. An ANOVA of the mean accuracy data with stimulus duration (100 vs. 400 ms) and trial type (precritical vs. postcritical) revealed a main effect for stimulus duration only, $F(1, 23) = 10.32$, $p < .01$, revealing better performance with the short than with the long stimulus duration (0.82 vs. 0.72). The other effects were not significant, $F\text{s} < 1$.

As before, confidence intervals were computed for the proportion correct in the critical trial, and it was tested whether the values statistically predicted by means of linear regressions from the proportion correct in the precritical and the postcritical trials would fall within this confidence interval. (Because stimulus duration had a significant impact on performance, only those trials of a block were used that matched the SOA of the critical trial.) Table 1 gives an overview of the results. These tests revealed that the performance in the 100 ms stimulus duration condition was not worse in the critical trial than in the precritical or the postcritical trials. In contrast, with the 400 ms stimulus

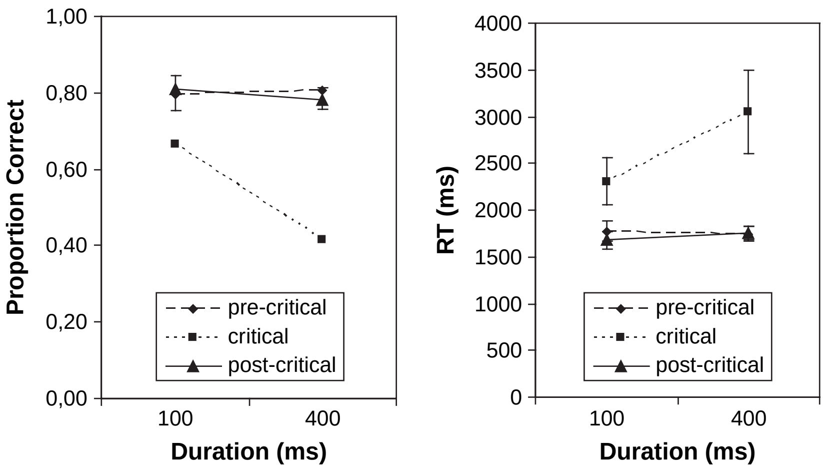

Figure 3. Results from Experiment 2 (see also caption of Figure 2).

duration, performance in the critical trial was worse than in both the precritical and the postcritical trials.

We analysed response latencies as an indicator of distraction and as an implicit measure of surprise. (Response latencies greater than 4000 ms were excluded, which pertained to three participants, all in the 400 ms duration condition.) An ANOVA using trial type (precritical, critical, postcritical) and stimulus duration (100 vs. 400 ms) as independent variables revealed a main effect of trial type only, $F(2, 38) = 21.7$, $p < .001$, reflecting longer latencies in the critical trial (2381 ms) than in the precritical (1726 ms) and in the postcritical (1684 ms) trials. The Trial × Duration interaction was not significant, $F(2, 38) < 1$, revealing the RT increase was similar in the 100 ms and the 400 ms duration conditions.

Results from interviewing participants revealed that only 4% missed the display change at all (one participant in the 400 ms duration conditions). Seventy-nine per cent of the participants said that they had seen the display change and were able to describe it correctly. Seventeen per cent of the participants correctly reported the colour but attributed it to the letter. There were no significant differences between the conditions, $\chi^2(1;\ N = 24) < 1$ (partially correct and incorrect answers were collapsed for the analysis).

Discussion

The results were similar to those in Experiment 1: There was virtually no performance decrement in the critical trial when the stimulus duration was 100 ms, but a pronounced performance decrement in the critical trial when the stimulus duration was 400 ms. This is a first indication that the elapsed time between the onset of the colour cues and the letters in the critical trial is not solely responsible for delayed attentional capture of the new colour, but that stimulus duration is at least one additional determinant.

GENERAL DISCUSSION

The present results add to the existing evidence showing that an unannounced colour singleton can capture attention. They complement previous research in showing that surprise singletons have opposite effects on concurrent task performance when presented at the position of the target or of a distractor: While performance in a difficult task improves with a target singleton, it is impeded with a distractor singleton. In addition, the results from Experiment 1 reveal a time course of the detrimental effects for distractor surprise singletons that is analogous to the time course of the beneficial effects for target surprise singletons (Horstmann, 2006): Evidence for attentional capture is weak with a short SOA (100 ms) but strong with long SOAs (400 ms). This result supports the hypothesis that attention capture has a late onset, but is at odds with the interference explanation proposing that the lag in performance benefits is due to prioritised processing of the expectancy-discrepant aspects of the surprise stimulus. This account predicts the distractor surprise singleton to impede performance also, and foremost, at shorter SOAs.

Experiment 2 asked whether the distinct time course for surprise capture is mainly due to the time elapsed between the presentation of unannounced singleton and target, or to stimulus duration. The results were clear-cut: Stimulus duration was a powerful moderator of surprise capture. Apparently, the stimulus must be presented for a minimal duration to exhibit its full effect on the deployment of spatial attention.

Awareness was not strongly influenced by SOA or duration. IB rates were 19% and 21% in Experiments 1 and 2, which is lower than in Gibson and Peterson's (2001) experiment (37%). Because stimulus duration was similar (100 ms without mask here, 143 ms plus energy mask in Gibson & Peterson), SOA is the more probable factor for the low IB rates. Participants in the Gibson and Peterson study may have switched more quickly from distributed attention (beginning of the trial) to focused attention (with the onset of the letters). Assuming that the computation of salience requires distributed attention and that participants distribute attention until the letters are presented and they switch to focal attention on individual letters, it follows that participants viewed the singleton display longer in a distributed attention mode in the present experiment ($SOA > 0$) than in the Gibson and Peterson experiment ($SOA = 0$).

The present results show that implicit and explicit measures of attention can dissociate, and—by implication—do not form converging operations but separate categories. Apparently, awareness of feature singletons does not depend on focal attention. Moreover, the IB results discount the possibility that the lack of attentional capture with a 100 ms SOA/100 ms duration is simply due to a lack of information about the presence of the singleton.

It should be noted that the present results do not indicate that awareness precedes attention by 300 ms, because awareness could have occurred at any time between the presentation of the singleton and the question following the trial. That is, it is even possible that awareness occurred only in response to the question by retrieving the respective memory trace. The present results rather indicate that certain stimulus conditions suffice to permit awareness without permitting attentional effects to be observed.

An analysis of the response latencies revealed interference in the critical trial in all conditions. That interference in Experiment 1 was smaller with the short SOA is consistent with previous research: For instance, Niepel et al. (1994), found interference to be at a maximum with a 500 ms SOA between surprise stimulus and target, probably because the surprise response is too slow to outrun the response-related processes with short SOAs but fast enough with long SOAs.

According to Horstmann (2002), the latency increase mainly reflects decision-level processing instigated by surprise, although it might also reflect behaviour inhibition. When the latency increase is interpreted as an indicator of interference, it follows that an unannounced singleton presented in an unattended location (i.e., in the 100 ms duration condition, where no attention capture was found) can induce interference. This is consistent with the assumption that detecting a discrepancy is an automatic process that does not necessitate focal attention.

The results have implications for a recent model by Most et al. (2001) to explain inattentional blindness. These authors suggested that unexpected stimuli enter awareness either because they capture attention by virtue of being confused with a possible target (due to their similarity to the targets defining feature) or because of their saliency. This model suggests that shifts of attention must precede awareness. However, the present experiments found just the opposite: Participants often noticed the new colour, but they did not always shift attention to its location. Note that, according to Horstmann (2005), saliency alone is not sufficient to elicit an orienting response, but that the stimulus must in addition be expectancy discrepant.

The result that stimulus duration is as important as SOA in the present experiments suggests that the processes underlying surprise capture require a sufficiently stable stimulus representation. One possibility is that the discrepancy detection is triggered only with a stable representation; the other that the attentional shift requires a visible target. The first alternative may appear implausible given that most participants reported the unexpected singleton, which implies that they not only noticed it but also recognized that it was different from the context. Further research is clearly needed.

Is the performance drop with an unannounced distractor singleton due to covert or to overt shifts of attention? Because covert shifts often occur quickly after stimulus onset, while overt shifts have a latency of about 180–200 ms (e.g., Becker & Jürgens, 1979), one might think that the attentional effects are caused by overt shifts of attention. This possibility is plausible, because usually there is a close correlation between the focus of covert and overt attention. Participants in the present experiments were instructed to retain fixation at the centre of the screen throughout the trial, but given that the attention shift was involuntary, it is not unlikely that participants did not follow this instruction in the critical trial. However, for the same reason of a close correlation between covert and overt shifts of attention, this possibility does not invalidate the interpretation of the performance data as an indication of shifts of attention. Note also that the letters are of sufficient size that they could be identified without the acuity gain achieved by eye movements.

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