Psychonomic Bulletin & Review (2021) 28:1538–1544
https://doi.org/10.3758/s13423-021-01899-9

BRIEF REPORT

Selection history modulates the limit of visual awareness in color perception

Zhe Chen[1] · Makayla Szu-yu Chen[1]

Accepted: 7 February 2021 / Published online: 4 May 2021

Abstract

Among studies on the limit of conscious representation of color at a given instant, some have shown evidence of momentary awareness of only a single color, while others have not, leading to uncertainty about the factors that influence the limit. In two experiments, we explored the role of selection history, or recent experience with a trial, which is known to influence the representations of task stimuli and responses. Two color patches were briefly displayed either simultaneously or sequentially. In Experiment 1, we presented the two types of trials either in separate blocks or in interleaved couplets. In the former case, participants could deploy optimal attentional control setting in response to different types of trials with little cost by using recent experience with a preceding trial and prior knowledge. In the latter case, reconfiguring attentional control setting after each trial would be costly. In Experiment 2, we mixed the two types of trials randomly within a block during testing, but re-grouped them in data analyses such that the same type of trials was either repeated or not repeated. The results show that accuracy was comparable between the simultaneous and sequential trials in the block condition in Experiment 1 and in the repeat condition in Experiment 2, suggesting that two colors were perceived at a time. These results indicate that selection history plays an important role in the limit of visual awareness in color perception and that the finding of single-color perception reported in previous research might not be a general phenomenon.

Keywords Selection history · Attentional control setting · Visual attention · Visual · Feature

Introduction

Many everyday activities such as searching for an orange in a fruit basket or a red car in a crowded parking lot require us to perceive multiple colors in a visual scene. However, despite this ubiquitous use of color, how many colors we can consciously perceive at a given moment is a topic of much controversy. According to the Boolean map theory (Huang et al., 2007; Huang & Pashler, 2007), there is a severe limit in instant conscious awareness or "access" of information, a term Huang and colleagues coined to refer to the content of information that is able to reach the stage of consciousness. While we have access to multiple locations at a time, for object features such as color, size, orientation, shape, and so on, the unit of access is limited to one feature value per dimension. In other words, if a display consists of a red square and a blue square, in terms of color perception, only red or blue, but not both, can reach awareness at a given instant.

One line of evidence in support of single-feature access comes from experiments that use a simultaneous/sequential paradigm. In one experiment, Huang et al. (2007, Experiment 1) showed participants two briefly displayed colored squares that appeared either concurrently (the simultaneous condition) or sequentially (the sequential condition) in alternate displays. This was then followed by a single test probe. In different tasks, participants judged whether the color or location of the test probe matched the color or location of one of the targets. For the color task, responses were more accurate in the sequential than in the simultaneous condition. For the location task, no difference was found. These results are consistent with the proposal that we have simultaneous access to more than one location, but not to more than one color.

However, there have also been studies that have shown different results (e.g., Fitousi, 2019; Hao et al., 2018; Mance et al., 2012; Miller et al., 2014). Using a paradigm similar but

✉ Zhe Chen
zhe.chen@canterbury.ac.nz

[1] School of Psychology, Speech and Hearing, University of Canterbury, Private Bag 4800, Christchurch, New Zealand

not identical to that in Huang et al. (2007), Mance et al. found equivalent performance in a color task between the simultaneous and sequential conditions when the target stimuli consisted of two colors. When the number of stimuli increased to three or four, accuracy was higher in the sequential than the simultaneous condition. Miller et al. also found comparable performance between the simultaneous and sequential conditions for two colors. These results suggest that the unit of access is beyond one color at a time.

What might cause the differences in results between these studies? Mance et al. (2012) noted several built-in contingencies in Huang et al. (2007). These contingencies included systematic pairing of target colors, systematic pairing of colors with locations, and temporal contingency in the sequential condition such that the red or green stimulus always preceded the blue or yellow stimulus. Mance et al. show that in the trials with the contingencies performance was superior in the sequential to the simultaneous condition, replicating the results of Huang et al. However, in the trials without the contingencies, there were no reliable differences between the two conditions.

Mance et al.'s (2012) study was not designed to identify the exact factor that affected the unit of access in color perception. In the two experiments reported here, we investigated the role of selection history. Although the deployment of a specific attentional control setting is traditionally thought to be influenced primarily by top-down factors such as the current selection goal and bottom-up factors such as the salience of the target relative to distractors, there is increasing evidence that past experience, or selection history, also plays an important role (see Awh et al., 2012, and Kristjànsson & Campana, 2010, for reviews). Selection history has been found to affect performance immediately (e.g., Chen & Cave, 2015; Leonard & Egeth, 2008; Maljkovic & Nakayama, 1994), across different blocks of trials (e.g., Leber & Egeth, 2006; Yeh et al., 2014), and even after a week (e.g., Leber et al., 2009). In Maljkovic and Nakayama, participants searched for an odd-colored target among distractors of a homogeneous color. The target could be one of two colors, and the task was to determine the target's shape. Responses were faster and more accurate when the color of the target was repeated compared with when it changed, indicating inter-trial priming. Leber and Egeth further demonstrated the persistence of a learned attentional set. In their study, participants searched for color-defined targets in a stream of rapidly presented stimuli. In the training phase, one of two attentional sets (i.e., a feature search mode vs. a singleton search mode), but not both sets, could be used to perform the task. In the test phase, both attentional sets could be used. Interestingly, participants continued using the same attentional set despite the option to use a different one. These results indicate that past experience with a task plays an important role in guiding the selection of a specific attentional control setting.

With regard to the present study, it is possible that the optimal attentional control setting for the stimuli presented in a simultaneous versus sequential trial may depend on how the two types of trials are grouped. Because the targets are presented concurrently in the simultaneous trials, the extent of attention zoom needs to be broader and the demand for attentional resources greater. When the two types of trials are grouped separately, participants can use their experience in a preceding trial and knowledge to deploy the optimal attentional control setting. In contrast, when the two types of trials are mixed within a block, switching between different attentional control settings can be difficult, if not impossible. As the demand for attentional resources is higher when the targets appear simultaneously rather than sequentially (we discuss this in more detail in the *General discussion*), with a sub-optimal attention control setting, performance should be worse in the simultaneous than the sequential trials.

In the two experiments reported here, we investigated the role of selection history in color perception by varying the way in which the simultaneous and sequential trials were grouped. If the pattern of data between the two types of trials differed as a function of grouping, this would indicate that selection history played a role in the unit of access in color perception.

Experiment 1

In Experiment 1, the simultaneous and sequential trials were grouped in two different ways. In the block condition, they were presented in different blocks. In the interleave condition, we followed the method used by Huang et al. (2007) and presented the two types of trials in couplets. Lower accuracy in the simultaneous than the sequential trials in the interleave condition but not in the block condition would indicate that selection history could have played a role in the results of Huang et al.

Method

Participants Thirty undergraduate students from the University of Canterbury took part in the experiment in exchange for course credits. This sample size was based on Experiment 1 in Huang et al. (2007). As the authors did not report the effect size, we calculated it using the method described in Lakens (2013). The effect size was η_p^2 = 0.46. Assuming a smaller effect size of η_p^2 = 0.20, we performed a power analysis with G*Power 3.1 (Faul et al., 2009). For α = 0.05 and 95% power, the recommended sample size was 26. We used a sample of 30 in both Experiment 1 and Experiment 2.

Apparatus and stimuli Stimuli were presented on a PC with a 24-in. monitor, and E-Prime was used to present the stimuli and collect responses. Participants were tested individually in two dimly lit rooms at a viewing distance of about 60 cm.

All the stimuli were presented on a black background (see Fig. 1). Each trial started with a central fixation, one or two target displays depending on the experimental condition, a mask following each target display, and a probe requesting a response. The fixation was a white cross that subtended 0.3°. On simultaneous trials, two 1.6° color squares, selected randomly without replacement from a target set that consisted of red (RGB: 255, 0, 0), green (RGB: 0, 128, 0), blue (RGB: 0, 0, 255), and yellow (RGB: 255, 255, 0) color patches, were displayed at two of four possible locations at the corner of an invisible square that subtended 4.8°. On sequential trials, two squares of different colors were presented sequentially and in different locations. In both conditions, the targets on a given trial always had different colors, and both the color and their locations were randomly selected with equal probability. The mask display consisted of four identical multi-color squares. The size of each square was the same as that of the target, and the four squares were presented at the four possible locations of the targets. The probe was a single color square. It matched one of the two targets on half the trials. On the rest of the trials, it was equally likely to be one of the two colors that did not appear on that trial.

Design and procedure The experiment used a 2 × 2 repeated-measures design with Grouping (block vs. interleave) and Presentation (simultaneous vs. sequential) as the principal factors. Figure 1 shows the procedure. Each trial started with a 400-ms fixation followed by a blank screen of 400 ms. In the simultaneous condition, one target display, which consisted of two color squares, would then appear concurrently. In the sequential condition, two target displays, each consisting of one color square, would appear one after the other. In both conditions, the duration of the target display varied across trials based on performance (see details below). The offset of the target display would trigger the onset of a 200-ms mask, and then a 500-ms blank screen. Afterwards, a test probe would appear at the center of the screen. It would remain on the screen until response. There was no intertrial interval. The task was to judge whether the probe matched one of the targets. Participants pressed the "J" key if the two were the same, and the "K" key if they were different. Accuracy rather than speed was emphasized.

In both the block and interleave conditions, the initial duration of the target display was 116 ms. Performance was assessed every 12 trials or six couplets. If accuracy was between 65% and 75%, there was no change in duration. If accuracy exceeded 75%, the duration would decrease by 17 ms. If accuracy fell below 65%, the duration would increase by 17 ms. The maximum duration was 200 ms and the minimum duration was 33 ms.

Each participant completed two sessions of trials with a short break between the sessions. In one session (the block condition), there were three blocks of simultaneous and sequential trials, with each block consisting of 48 simultaneous trials or 48 sequential trials. Participants were informed about the type of trials at the beginning of each block. The order of the block was randomized across participants. In the other session (the interleave condition), the two types of trials were

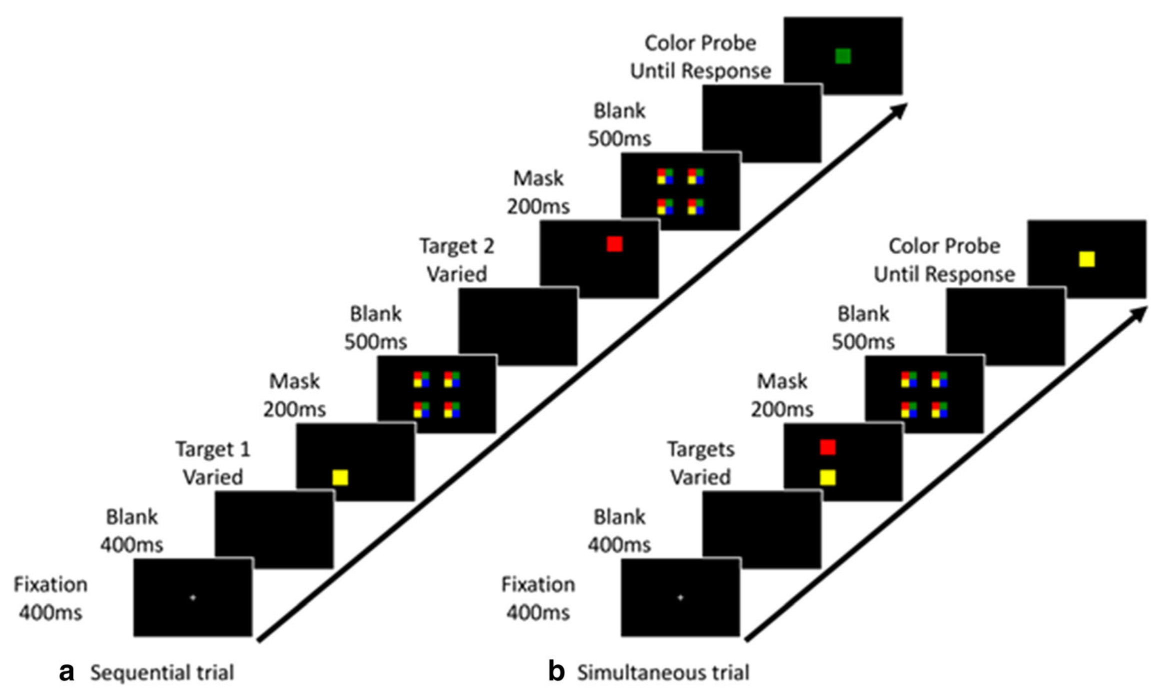

Fig. 1 Examples of trials from Experiment 1. **a** A sequential trial. **b** A simultaneous trial

presented in couplets, with each couplet starting with a sequential trial followed by a simultaneous trial. Altogether, there were 144 couplets. The order of the sessions was counterbalanced across the participants, and in both sessions, participants could take a break after every 48 trials. In total, each participant completed 576 trials in addition to 24 practice trials, with 12 trials before each session. The entire experiment took about 30 min to complete.

Results and discussion

Figure 2 shows the results. One participant's data were excluded due to anticipatory responses (18.8% trials faster than 200 ms). A 2 × 2 repeated-measures analysis of variance (ANOVA) showed higher accuracy in the sequential (75.3% correct) than the simultaneous (72.6% correct) trials, $F(1, 28) = 6.02$, $MS_e = 33$, $p = .02$, $\eta_p^2 = 0.18$. Grouping and Presentation interacted, $F(1, 28) = 5.57$, $MS_e = 16$, $p = .03$, $\eta_p^2 = 0.17$. Accuracy was higher in the sequential (75.9% correct) than in the simultaneous (71.5% correct) trials in the interleave condition ($p = .002$), but not in the block condition (74.6% and 73.7% correct in the sequential and simultaneous trials, respectively, $p = .85$). No significant effect of Grouping was found ($p = .31$).

These results indicate that selection history can affect the unit of access in color perception. In the block condition, in addition to knowing the trial type, participants could let the processing strategies on a given trial be determined by recent experience in a preceding trial. As there was little cost in deploying the optimal attentional control setting, performance was comparable between the two types of trials. In the interleave block, although participants still had foreknowledge about a trial, it was unlikely that knowledge alone could help them reconfigure the optimal attentional control setting on a trial-by-trial basis. Previous research on task switching has shown that the cost in performance, which is typically found when participants have to switch between two cognitive tasks, can be reduced but not eliminated, even under ideal conditions such as when participants have both the knowledge and time to prepare for the switch (e.g., for reviews, see Kiesel et al., 2010; Monsell, 2003). Rogers and Monsell (1995) demonstrated this in a series of elegant experiments. Participants performed two tasks that were either blocked or alternated on a predictable schedule. Compared to the block condition, performance was impaired in the switch condition even with long response-stimulus intervals (e.g., over 1,000 ms). Furthermore, the switch cost occurred only on the first trial of a run in the new task. Based on these and related results, the researchers proposed that the activation of a task set, i.e., the optimal control setting for a task, requires the presence of task-relevant stimuli. In the present study, although our participants did not switch between different tasks, the two types of trials involved different types of presentation that required different attentional control settings and different amounts of effort. With the two types of trials presented in couplets, it would be difficult to deploy the optimal attentional control setting on a given trial. Consequently, performance was impaired in the simultaneous trials relative to the sequential trials.

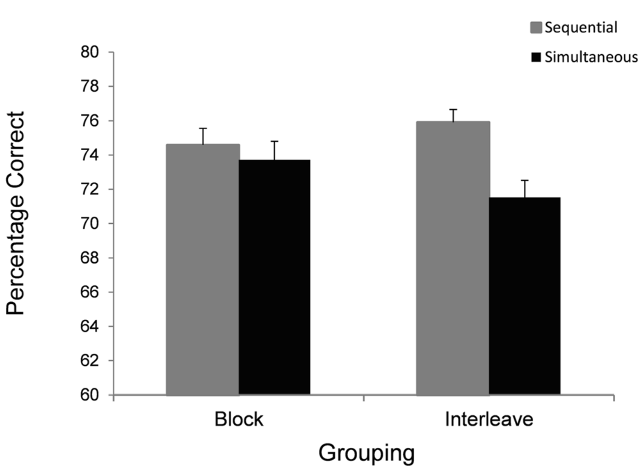

Fig. 2 Results from Experiment 1. Error bars show the within-subjects standard error of the mean (Cousineau, 2005)

Experiment 2

In Experiment 2, we further examined the role of recent experience in conscious access to color. We mixed the simultaneous and sequential trials randomly within a block during testing. In data analyses, we separated the trials into a "repeat" condition, in which the same type of trials appeared in *n* and *n*-1 trials (i.e., a simultaneous trial preceded by a simultaneous trial, and vice versa for a sequential trial), from a "switch" condition, in which different types of trials occurred in *n* and *n*-1 trials (i.e., a simultaneous trial preceded by a sequential trial, or vice versa). If recent experience affects the number of colors that can be accessed at a given moment, participants should show different patterns of data between the "repeat" and "switch" conditions.

Method

Experiment 2 was identical to Experiment 1 except that the two types of trials were randomly intermixed within a block. Thirty new participants took part in the study.

Results and discussion

To examine the effect of recent experience, we re-grouped the data into the "repeat" versus the "switch" condition. Figure 3 shows the results. A 2 × 2 repeated-measures ANOVA with TrialType (repeat vs. switch) and Presentation (simultaneous

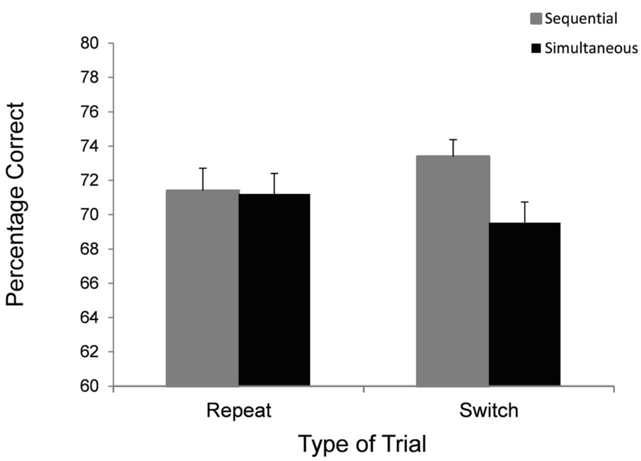

Fig. 3 Results from Experiment 2. Error bars show the within-subjects standard error of the mean

vs. sequential) revealed lower accuracy in the simultaneous (70.4% correct) than the sequential condition (72.4% correct), $F(1, 29) = 5.93$, $MS_e = 21$, $p = .02$, $\eta_p^2 = 0.17$. Moreover, the two factors interacted, $F(1, 29) = 5.55$, $MS_e = 18$, $p = .03$, $\eta_p^2 = 0.16$. Accuracy was lower in the simultaneous (69.5% correct) than the sequential (73.4% correct) condition in the switch trials ($p < .01$), but not in the repeat trials (71.2% in the simultaneous condition and 71.4% in the sequential condition, $p = .99$). There was no reliable effect of TrialType ($p = .84$).

The most important finding of Experiment 2 is the different pattern of data between the repeat and switch conditions, with higher accuracy in the sequential than the simultaneous trials in the switch condition but not in the repeat condition. These results indicate that recent experience influenced participants' processing strategies and consequently their performance. As participants had no prior knowledge about the type of trial, a reasonable strategy would be to "expect" the same type to continue (Theeuwes et al., 2004).[1] Such a strategy would lead to an appropriate attentional control setting in the repeat condition, but not necessarily in the switch condition. The results of the experiment are consistent with this interpretation.

General discussion

Using a simultaneous/sequential paradigm, the present study shows that conscious representation of color is not limited to one color at a time. In Experiment 1, the simultaneous and sequential trials were grouped in different blocks or in an interleaved way. The results of Huang et al. (2007) were replicated in the interleave but not the block condition. In Experiment 2, all the trials were randomly mixed within a block in testing, but re-arranged into a "repeat" versus a "switch" condition in data analyses. Accuracy was higher in the sequential than the simultaneous trials in the switch condition, but not in the repeat condition. These results show that the unit of access for color perception is not fixed, and that selection history modulates the amount of information that can be accessed at a given instant.

It is important to note that although our results are inconsistent with the single-feature access proposed in the Boolean map theory, the single-feature access was proposed as a contrast to the multiple-location access (Huang, personal communication, December 2020), and our results do not challenge this feature/location distinction, which has been demonstrated in multiple studies (Huang, 2010a, 2010b; Huang et al., 2007). Processing asymmetries between location and object features have also been found in other lines of research, including attentional guidance, selection efficiency, and perceptual consequences (e.g., Chen, 2009; Chen & Wyble, 2015; Tsal & Lavie, 1993; also see Lamy & Tsal, 2001, for a review).

What might have caused the different results between the present study and Huang et al. (2007)? We attribute the differences to selection history, with the key factors being the extent of attentional zoom and the amount of attentional resources, both of which are known to be influenced by task demands (LaBerge, 1983; LaBerge et al., 1991). As the simultaneous trials require the processing of two targets concurrently, a broader attentional zoom and more attentional resources are needed compared with the sequential trials. In a block design, participants could rely on recent experience with a preceding trial for the deployment of the optimal attentional control setting. Knowing the type of trial in advance might also help them make deliberate adjustment of effort as compensation for the task difficulty, leading to comparable performance between the simultaneous and sequential trials.[2] These results are also consistent with the findings in Mance et al. (2012) and Miller et al. (2014). Both studies used a block design.

When an optimal attentional control setting cannot be deployed in advance such as in the interleave conditions in Experiment 1 and Huang et al. or in Experiment 2, participants may "expect" the same trial type to continue (Theeuwes et al., 2004). In the repeat condition, this strategy will work well for

[1] To explore the interaction between TrialType and Presentation further, we conducted two t tests to compare participants' performance between the repeat and switch trials when the targets were presented simultaneously and when they were presented sequentially. In the simultaneous condition, accuracy was numerically higher in the repeat trials (71.2% correct) than in the switch trials (69.5% correct), $t(29) = 1.57$, $p = 0.06$, $d = .29$, indicating that when a trial had a relatively high demand for attentional resources (i.e., a simultaneous trial), changing from the sequential to simultaneous presentation impaired performance. In contrast, in the sequential condition, accuracy was lower in the repeat trials (71.4% correct) than in the switch trials (73.4% correct), $t(29) = 1.70$, $p = 0.047$, $d = .31$, indicating that when a trial had a relatively low demand for attentional resources (i.e., a sequential trial), changing from the simultaneous to sequential presentation facilitated performance. This pattern of data is consistent with the notion that in a randomized design participants may "expect" the same trial type to continue. We thank an anonymous reviewer for suggesting the above analyses.

[2] We thank Liqiang Huang for pointing out this possibility.

both types of trials. In the switch condition, this strategy will favor the sequential trials but disadvantage the simultaneous trials. When a sequential trial follows a simultaneous one, the attentional control setting for a simultaneous trial (e.g., a relatively broad attentional zoom and sufficient attentional resources) will not negatively affect the allocation of attention to the target in the sequential trial as the target will capture attention in a stimulus-driven way (Jonides & Yantis, 1998). In contrast, when a simultaneous trial follows a sequential one, the attentional control setting for a sequential trial will impact the processing of the targets negatively as attention needs to be divided between the targets. If insufficient attentional resources are allocated for the trial, performance will suffer, resulting in lower accuracy in the simultaneous than the sequential trials. The results of the present study support this account.

In addition to the unit of access in color perception, the effect of selection history has been reported in studies that manipulate perceptual load. Distractor processing is typically larger in the low- than the high-load condition when the two conditions were in separate blocks (e.g., Lavie, 1995; Lavie & Cox, 1997), but not when they were intermixed within a block (e.g., Benoni et al., 2013; Murray & Jones, 2002), when the data were grouped into repeat versus switch trials (e.g., Biggs & Gibson, 2010; Theeuwes et al., 2004), or when the extent of attentional zoom was held constant across the conditions (e.g., Chen, 2003; Chen & Cave, 2013, 2016).

Effects of selection history have also been reported in visual search studies (e.g., Chun & Jiang, 1998; Leber & Egeth, 2006; Yeh et al., 2014), including those in which the target was a singleton (e.g., Bravo & Nakayama, 1992; Chen & Cave, 2015; Leonard & Egeth, 2008; Maljkovic & Nakayama, 1994; Müller et al., 2003). The latter studies are particularly interesting because searching for a singleton can be accomplished easily via stimulus-driven processes due to its salience. However, despite target pop-out, recent experience can still provide an additional benefit, making responses even faster (see Lamy & Krisjánsson, 2013, for a review).

Although in many previous studies, including Experiment 1 in the present study, it is impossible to distinguish between the role of foreknowledge and that of selection history in modulating performance, Maljkovic and Nakayama (1994, Experiment 4) show that the contribution by foreknowledge may be very limited. Using a shape-comparison task with the target defined by a unique color and the target color changed in a predictable AABB sequence, the researchers found comparable performance between a passive condition, in which participants were instructed to relax and respond to what they saw, and an active condition, in which participants subvocalized the upcoming target's color. These results indicate that intertrial priming may be out of top-down control, a result in line with the pattern of data observed in Experiment 2 and in the interleave condition in Experiment 1. The results in the present study are also consistent with the proposal that performance is influenced by a variety of factors including an observer's behavioral goal, selection history, and the properties of the stimulus display (Awh et al., 2012).

In summary, we have shown that selection history plays an important role in the number of colors that can be consciously perceived at a time. When an appropriate attentional control setting can be deployed, it is possible to perceive two colors. Our results also show the flexibility of the visual system, suggesting that perception is the combined result of many different factors.

Acknowledgements We thank Liqiang Huang and an anonymous reviewer for their helpful comments on an earlier version of this paper.

References

Awh, E., Belopolsky, A. W., & Theeuwes, J. (2012). Top-down versus bottom-up attentional control: A failed theoretical dichotomy. *Trend in Cognitive Science*, 16, 433–443. https://doi.org/10.1016/j.tics.2012.06.010

Benoni, H., Zivony, A., & Tsal. Y. (2013). Attentional sets influence perceptual load effects, but not dilution effects. *Quarterly Journal of Experimental Psychology,* 67, 785–792. https://doi.org/10.1080/17470218.2013.830629

Biggs, A. T., & Gibson, B. S. (2010). Competition between color salience and perceptual load during visual selection can be biased by top-down set. *Attention, Perception, & Psychophysics*, 72, 53–62. https://doi.org/10.3758/APP.72.1.53

Bravo, M. J., & Nakayama, K. (1992). The role of attention in different visual-search tasks. *Perception & Psychophysics*, 51, 465–472. https://doi.org/10.3758/BF03211642

Chen, Z. (2009). Not all features are created equal: processing asymmetries between location and object features. *Vision Research*, 49, 1481–1491. https://doi.org/10.1016/j.visres.2009.03.008

Chen, Z. (2003). Attentional focus, processing load, and Stroop interference. *Perception & Psychophysics*, 65, 888–900. https://doi.org/10.3758/BF03194822

Chen, Z., & Cave, K. R. (2013). Perceptual load vs. dilution: The role of attentional focus, stimulus category, and target predictability. *Frontiers in Psychology*, 4, 327. https://doi.org/10.3389/fpsyg.2013.00327

Chen, Z., & Cave, K. R. (2015). Singleton search is guided by knowledge of the target, but maybe it shouldn't be. *Vision Research*, 115, 92–103. https://doi.org/10.1016/j.visres.2015.08.012

Chen, Z., & Cave, K. R. (2016). Zooming in on the cause of the perceptual load effect in the go/no-go paradigm. *Journal of Experimental Psychology: Human Perception and Performance*, 42, 1072–1087. https://doi.org/10.1037/xhp0000168

Chen, H., & Wyble, B. (2015). The location but not the attributes of visual cues are automatically encoded in working memory. *Vision Research*, 107, 76–85. https://doi.org/10.1016/j.visres.2014.11.010

Chun, M. M., & Jiang, Y. (1998). Contextual cueing: Implicit learning and memory of visual context guides spatial attention. *Cognitive Psychology*, 36, 28–71. https://doi.org/10.1006/cogp.1998.0681

Cousineau, D. (2005). Confidence intervals in within-subject designs: A simpler solution to Loftus and Masson's method. *Tutorials in*

Quantitative Methods for Psychology, 1, 42–45. https://doi.org/10.20982/tqmp.01.1.p042

Faul, F., Erdfelder, E., Buchner, A., & Lang, A. –G. (2009). Statistical power analyses using G Power 3.1: Test for correlation and regression analyses. *Behavior Research Methods*, 41, 1149–1160. https://doi.org/10.3758/BRM.41.4.1149

Fitousi, D. (2019). Can we perceive two colors at the same time? A direct test of Huang and Pashler's (2007) Boolean map theory of visual attention. *Attention, Perception, & Psychophysics*, 81, 1532–1550. https://doi.org/10.3758/s13414-019-01665-z

Hao, R., Becker, M. W., Ye, C., Liu, Q., & Liu, T. (2018). The bandwidth of VWM consolidation varies with the stimulus feature: Evidence from event-related potentials. *Journal of Experimental Psychology: Human Perception and Performance*, 44, 767–777. https://doi.org/10.1037/xhp0000488

Huang, L., (2010a). What is the unit of visual attention? Objects for selection, but Boolean map for access. *Journal of Experimental Psychology: General*, 139, 162–179. https://doi.org/10.1037/a0018034

Huang, L. (2010b). Characterizing the nature of visual conscious access: The distinction between features and locations. *Journal of Vision*, *10*(10):24, 1–17. https://doi.org/10.1167/10.10.24

Huang, L., & Pashler, L. (2007). A Boolean map theory of visual attention. *Psychological Review*, 114, 599–631. https://doi.org/10.1037/0033-295X.114.3.599

Huang, L., Treisman, A., & Pashler, L. (2007). Characterizing the limits of human visual awareness. *Science*, 317, 823–825. https://doi.org/10.1126/science.1143515

Jonides, J. & Yantis, S. (1998). Uniqueness of abrupt visual onset in capturing attention. *Perception & Psychophysics*, 43, 346–354. https://doi.org/10.3758/BF03208805

Kiesel, A., Steinhauser, M., Wendt, M. Falkenstein, M., Jost, K., Philipp, A. M., & Koch, I. (2010). Control and interference in task switching – a review. *Psychological Bulletin*, 136, 849–874. https://doi.org/10.1037/a0019842

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

LaBerge, D. (1983). Spatial extent of attention to letters and words. *Journal of Experimental Psychology: Human Perception and Performance*, 9, 371–379. https://doi.org/10.1037/0096-1523.9.3.371

LaBerge, D., Brown, V., Carter, M., Bash, D., & Hartley, A. (1991). Reducing the effects of adjacent distractors by narrowing attention. *Journal of Experimental Psychology: Human Perception and Performance*, 17, 65–76. https://doi.org/10.1037/0096-1523.17.1.65

Lakens, D. (2013). Calculating and reporting effect sizes to facilitate cumulative science: A practical primer for t-tests and ANOVAs. *Frontiers in Psychology*, 4, 863. https://doi.org/10.3389/fpsyg.2013.00863

Lamy, D. F., & Kristjánsson, Á. (2013). Is goal-directed attentional guidance just intertrial priming? A review. *Journal of Vision*, 13(3):14, 1–9. https://doi.org/10.1167/13.3.14

Lamy, D., & Tsal, Y. (2001). On the status of location in visual attention. *European Journal of Cognitive Psychology*, 13, 305–342. https://doi.org/10.1080/09541440125789

Lavie, N. (1995). Perceptual load as a necessary condition for selective attention. *Journal of Experimental Psychology: Human Perception and Performance*, 21, 451–468. https://doi.org/10.1037/0096-1523.21.3.451

Lavie, N., & Cox, S. (1997). On the efficiency of visual selective attention: Efficient visual search leads to inefficient distractor rejection. *Psychological Science*, 8, 395–398. https://doi.org/10.1111/j.1467-9280.1997.tb00432.x

Leber, A. B., & Egeth, H. E. (2006). Attention on autopilot: Past experience and attentional set. *Visual Cognition*, 14, 565–583. https://doi.org/10.1080/13506280500193438

Leber, A. B., Kawahara, J-I., & Gabari, Y. (2009). Long-term abstract learning of attentional set. *Journal of Experimental Psychology: Human Perception and Performance*, 35, 1385–1397. https://doi.org/10.1037/a0016470

Leonard, C. J., & Egeth, H. E. (2008). Attentional guidance in singleton search: An examination of top-down, bottom-up, and intertrial factors. *Visual Cognition*, 16, 1078–1091. https://doi.org/10.1080/13506280701580698

Mance, I., Becker, M. W., & Liu, T. (2012). Parallel consolidation of simple features into visual short-term memory. *Journal of Experimental Psychology: Human Perception and Performance*, 38, 429–438. https://doi.org/10.1037/a0023925

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

Miller, J. R., Becker, M. W., & Liu, T. (2014). The bandwidth of consolidation into visual short-term memory depends on the visual feature. *Visual Cognition*, 22, 920–947. https://doi.org/10.1080/13506285.2014.936923

Monsell, S. (2003). Task switching. *Trends in Cognitive Sciences*, 7, 134–140. https://doi.org/10.1016/S1364-6613(03)00028-7

Müller, H. J., Reimann, B., & Krummenacher, J. (2003). Visual search for single feature targets across dimensions: Stimulus- and expectancy-driven effects in dimensional weighting. *Journal of Experimental Psychology: Human Perception and Performance*, 29, 1021–1035. https://doi.org/10.1037/0096-1523.29.5.1021

Murray, J. E., & Jones, C. (2002). Attention to local form information can prevent access to semantic information. *The Quarterly Journal of Experimental Psychology A: Human Experimental Psychology*, 55, 609–625. https://doi.org/10.1080/02724980143000370

Rogers, R. D., & Monsell, S. (1995). Costs of a predictable switch between simple cognitive tasks. *Journal of Experimental Psychology: General*, 124, 207–231. https://doi.org/10.1037/0096-3445.124.2.207

Theeuwes, J., Kramer, A. F., & Belopolsky, A. V. (2004). Attentional set interacts with perceptual load in visual search. *Psychonomic Bulletin & Review,* 11, 697–702. https://doi.org/10.3758/BF03196622

Tsal, Y., & Lavie, N. (1993). Location dominance in attending to color and shape. *Journal of Experimental Psychology: Human Perception and Performance*, 19, 131–139. https://doi.org/10.1037/0096-1523.19.1.131

Yeh, Y.-Y., Lee, S.-M., Chen, Y.-H., & Chen, Z. (2014). Selection history modulates the effects of dual mechanisms on flanker interference. *Journal of Experimental Psychology: Human Perception and Performance*, 40, 2038–2055. https://doi.org/10.1037/a0037661