

Attentional Control Setting: Type, Quantity and Processing Stage

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Abstract: The attentional control setting is a search template containing target features. Individuals can establish attentional control settings based on the color, size, semantics, joint location-feature of stimulus and even relationships between targets and non-targets. When multiple targets exist, participants may establish multiple attentional control settings or a control setting based on the feature singleton item. However, the processing stage of the attentional control setting is still controversial. Future studies should further analyze the time course of attention control setting in different experimental paradigms to provide solutions to existing controversies, while examining the quantitative limits of attention control setting and the influence of distractor inhibition as a control setting on visual search.

Keywords: attention capture, attention control setting, processing stage

1. Introduction

People are unable to process all the information in a complex visual scene, and attention can help people choose a part of the information for deep processing. Therefore, it is very important to understand the guidance mechanisms of selective attention. Existing studies generally believe that attention can be guided either by bottom-up driven stimuli or top-down targets. The bottom-up account emphasizes the effect of stimulus salience on attention, the most salient stimuli in the environment automatically capture attention in a bottom-up way [1]. However, other researchers believe that attention is guided by top-down goals, the participants would establish an attentional control setting (Hereinafter referred to as the ACS) for the target characteristics, only stimuli matching the ACS could capture attention, and mismatched stimuli would be filtered out [2-4].

ACS refers to the participants attention bias to the target, pointing the attention adjustment to the attributes and characteristics related to the target [2]. The study of ACS has lasted for nearly 40 years, but there are still many controversies. For example, what characteristics can be used to establish ACS? How many ACSs can be established at once? Does the role of the ACS occur before, or after, attention capture? In order to summarize the research content and existing disputes of the ACS, this paper systematically review and summarize the relevant studies from the perspective of the type, quantity and processing stage, in order to provide some ideas for future research.

2. The type of attentional control setting

2.1. Characteristic-based attentional control setting

ACS can focus attention on a certain feature of the target to improve the search efficiency. Initially, the ACS can only be set broadly to a static discontinuity and dynamic discontinuity [5]. However, later studies show that the ACS can be further refined to a specific eigenvalue. For example, participants can establish ACSs for a specific color, size or a higher level of semantic concepts[6-9].

In addition, individuals can also establish an ACS by joint feature-position[10], and the cognitive processing stage was further explored [11]. They found that the joint ACS will affect the later attention selection rather than the early processing. However, all cues induce N2pc, which, in fact, indicates that the participants may not successfully establish the joint ACS. Therefore, researchers used the rapid serial visual presentation paradigm to study whether the participants could establish the ACS of the color-position combination [12]. The results indicate that the participants failed to establish the ACS based on the feature-position combination. However, when presented with distractor matching cues, the accuracy is significantly higher than no cue condition, indicating that the participant inhibited the distractor according to the color-position connection, thus more effectively selecting the correct coupling object that matched the target. It shows that inhibition may be an important or necessary process for implementing a joint ACS.

Through these studies, it can be found that the ACS is very flexible and can be established not only based on various features but also based on feature-position combinations. However, the joint ACS based on feature-position is unstable, and the reasons are not clear and deserve further study.

2.2. Relation-based attentional control setting

In addition to target feature and joint feature localization, individual attention can also establish relationship-based ACS, separating target from other non-targets around in a context-dependent manner [13-14]. This relational account suggests that the exact feature values of the target show high variability in the natural environment, bias attention towards the relationship between targets and non-targets may be more helpful for search [15-18]. It has recently been found that individuals can adapt relationship-based and feature-based ACSs. When both feature-based and relationship-based ACSs can be established, the participant will prefer to establish relationship-based ACSs; when one dimension can only be based on features and another dimension can be based on relationship or feature, participant will simultaneously establish ACSs based on features and relationship; when the relationship is not available, participant will choose feature-based ACSs [19].

Researchers further found that feature-based capture occurs only outside the attention window, while relationship-based capture occurs only within the attention window, with a dual separation mechanism [20]. However, the separation between these two captures may be due to different strategies. The relationship-based ACS can also occur outside the attention window with a global modulation effect [21]. And participants prefer to establish a relationship-based ACS when both features and relations are available [8] [21]. And when the relationship between the target and non-target is unpredictable, the ACS will bias the precise target features [22].

In summary, relational search is a preferred search strategy. When both relationship-based and feature-based ACS can be established, participants tend to establish relationship-based ACS. However, when the relationship is unpredictable, the participants will establish feature-based ACS.

3. Quantity of Attentional control settings

In the real world, people generally don't just search for one or one category of target, so how many ACSs can individuals establish at most? And what kind of ACS will be established? Previous studies

have explored this issue. When there is more than one target feature, it has been shown that participants tend to establish ACS based on the color singleton term to save cognitive resources and maximize the search efficiency [23-24]. However, other studies suggest that individuals can establish two ACSs based on target features [25-26] [16].

In conclusion, when there is more than one target feature, participants can establish the ACS based on multiple targets or establish the singleton control setting. Later studies may be considering further exploring the quantity upper limit and its preconditions that the ACS can be established.

4. The occurrence stage of the attentional control setting

4.1. Late processing phase - driven by bottom-up stimulation

Theeuwes and colleagues suggest that ACS acts during the detachment and transfer phases following attention capture. They conducted a series of studies using the additional singleton paradigm and proposed the attention shifts hypothesis. A significant stimulus on any physical feature captures attention, and top-down attention controls the regulation rate of dissociating from that stimulus after attention capture. If the cue matches the target, the rate of dissociating is slow, if the cue does not match the target, the attention dissociating is fast [1] [27-28]. Researchers use additional singleton paradigms to design different Stimulus-Onset Asynchrony (hereinafter SOA) to explore the time course of attention capture [27][29]. The result shows that when the time interval is relatively short, the distractor captures the attention, and when the time interval is longer, it is sufficient to inhibit the distractor. Therefore, they believe that the bottom-up physical salience factor acts in the early stage, and the top-down ACS acts in the later stage, the adjustment attention shifts to other locations after the distractor captures attention. They believe that the early stage is the stage of sensory processing and regulation, and the attention is captured by distractor, and in the middle stage, attention begins to shift from the current position in the form of inhibition, while the later stage is the transfer of attention resources, the attention is separated from the cue position and redirected, and irrelevant stimuli are completely suppressed.

These studies suggest that the physical salience of a stimulus is a determinant in capturing attention. ACS is an attention control mechanism regulated by the requirements of the target task. It helps the attention to escape and transfer from the irrelevant salient stimulus after the stimulus captures attention.

4.2. Early processing stage - driven by top-down target

If all salient stimuli initially capture attention, does the distractor-cue have an attention-capturing effect when the SOA is shortened? Researchers reduced the SOA to 35ms, finding the distractor may be inhibited before the stimulus appears [30]. The findings support top-down goal-driven capture theory in the early stages [4] [6]. The theory suggests that participants store targets in working memory or long-term memory, forming ACS. The ACS is like a filter, and stimuli that don't match the ACS are filtered and do not capture attention. And both target color in the irrelevant field and neutral color-induced P1 amplitude were significantly greater than distractor color [31]. It suggest that distractor is suppressed below baseline levels during early sensory processing stages.

In conclusion, whether the processing stage of ACS is in the early or late stages is still controversial. In the future, it is possible to provide solutions to the existing disputes by creating or improving experimental paradigms.

5. Summary and Outlook

5.1. Exploring the time course of the attentional control setting under different paradigms

The two most common paradigms in the study of ACS are the spatial cue paradigm and the additional singleton paradigm. The two paradigms differ greatly in the presentation time of the search screen. In the spatial cue paradigm, the time of the search screen is very short, there is time pressure. Participants are more likely to choose the most effective ACS to guide the search, and the results can better reflect the early attention guidance. However, in the additional singleton paradigm, the time of search screen is longer, individuals may have extra time and resources to allocate to the distractor, and the capture effect of the distractor will be found. Research has found that the different search screen presentation times affect the attention capture results [32]. Unfortunately, the study only used the additional singleton paradigm to set up different stimulus presentation times.

In addition, in the spatial cue paradigm, the cue type can be added without changing the primary search task, since the cue and the target are temporally separated. But, in the additional singleton paradigm, adding the neutral stimulus will greatly change the search task, because the color distractor will no longer be the only element with different colors [33], which makes the additional singleton paradigm, the distractor attention capture and inhibition effects have no real baseline comparison. Therefore, each paradigm has its advantages and drawbacks, and it is necessary to analyze the time course of attention control in the two paradigms using different SOA and experimental paradigms in the same study.

5.2. The scope of application and boundary conditions of the attentional control setting

In studies of ACS based on multiple target features, there are only two features [16] [34]. In general, default for ‘many’ is the number of three or more, but few studies have limited the scope of conclusions. It is easy to question whether ACS can be established when the number of features reaches the limit of the individual’s working memory load. In addition, what is the upper limit for the number of multiple ACSs? What are the preconditions? Further studies may still be needed.

5.3. The conditions and temporal dynamics of the inhibitory control setting

The role and regulatory mechanism of ACS in attentional capture is fully understood, while it is also very important to understand how multiple distractors are inhibited during visual search. However, the control setting of inhibition is not very clear. Previous studies have found that when the target is determined, the participants can establish ACS based on the target [3] [34]. However, the distractor is determined and the target is uncertain, the participant can establish two ACSs based on the two targets [16]. So, when the target exceeds the memory load, can the participant establish the inhibitory control setting based on the determined distractors? If successfully established, how does it interact with ACSs based on multiple targets? Examining the guiding role of inhibition direction in attention may help us to more fully understand individual search patterns and build more accurate models of attention. Therefore, in order to further promote the development of attention theory, the conditions and temporal dynamics of the control setting of the inhibitory direction may deserve further investigation.

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