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Subliminal Cueing in Visual Attention: Top-down and Bottom-up Processing

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Abstract

Exogenous subliminal cues have been shown to have both top-down and bottom-up effects. There are many research studies have confirmed that the effect of top-down variables dependent on cue characteristics. In response, other studies have attempted to exhibit 'purely' stimulus-driven attention capture. The superiority of attention capture effects and the level of superiority in top-down cues have not been evidenced previously. The present study attempted to observe differential effects of cues with different levels of task relevancy, in both valid and invalid cues. As an addendum, conditions with valid cues and incorrect feature match allowed for the exploration of same-location costs in subliminal cues. The results indicated attentional capture effects of all valid cues irrespective of the level of task relevance in subliminal conditions. The cues with the highest task relevancy led to the most attention capture. There were no inhibitory effects of invalid cues on attention capture in subliminal cues. The study reiterates the possibility of attentional mechanisms in same-location costs implicating processing outside of memory. Further, facilitation and inhibition of attention capture in subliminal cues may have two independent mechanisms. The inhibitory mechanism may be contingent to conscious awareness of cues. The result of the study shows how attention can be exogenously oriented without conscious awareness and what kinds of cues might be most effective. These findings can be useful in educational and training settings and other settings where sustained attention is crucial.

Keywords: Bottom-up Processing, Subliminal Cueing, Task-relevancy, Top-down, Visual Attention.

Introduction

Our visual attention is not just endogenously controlled but also influenced by exogenous factors (1-3). There are two kinds of processing – exogenous stimulus-driven and endogenous goal-driven. He posited that the exogenous system is the attentional system that responds to environmental stimuli. On the other hand, the endogenous system responds to our higher-order processes and works in a top-down manner (4-6). Top-down and bottom-up processing stem from an information processing viewpoint where cognition is seen as a form of information processing. Bottom-up processing is stimulus-driven, where external stimuli influence processing. On the other hand, top-down processing is affected by expectations and knowledge (7). McCormick (8) asserted that exogenous orientation could be achieved without the awareness of the individual – that is, the cues are *subliminal*. Subliminal processing refers to the processing of stimuli below the threshold of awareness. Even though the participants were unaware of attentional cues, there was a facilitatory effect on attention. The two systems, endogenous and exogenous, may not be discrete. The endogenous system can be affected by the characteristics of the cue. The provision of a 'target' elicits requirements for a task and by extension, task-relevancy. In line with this, Ansorge and Neumann (2) proposed that intentions and task relevancy influence the attentional control mechanisms, reflecting the differential efficacy of subliminal cues with different characteristics. McCormick asserted that subliminal cueing is an automatic process that is stimulus-driven. Many studies have concurred regarding the stimulus-driven nature of attention capture in subliminal cueing conditions (4, 5). Subliminal cueing in these studies ensured that the cue provided before the target display did not share features with the target. Feature-based matching cues are more goal-driven. This is a corollary to the evidence from single unit

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recordings that show that feature-based attention reflects top-down processing (9). Therefore, studies use cues that do not share similar features with the target to reflect stimulus-driven cueing. In a study with only non-matching cues, Schoeberl *et al*., (5) claimed that attention capture in subliminal cueing paradigms could be 'completely' stimulus-driven. They point out that previous study that claim stimulus-driven capture may still have top-down processes involved. The dots presented in the study by the author (7) made use of a dot that could have become a singleton as it held unique features in sharp contrast to a homogenous set of placeholders. This unique presentation could have induced a top-down contingent. Schoeberl and his colleagues employ a target discrimination paradigm to eliminate this possibility, ensuring that i) the cue does not share feature characteristics with the target; ii) the target was set among heterogenous distractors such that the target does not stand out as a singleton. The cues that were non-matching in terms of the feature were able to elicit cueing effects, thus, leading to the conclusion that attention capture using subliminal cues can be 'completely stimulus-driven' (5).

Early research on liminal cues shows that the orientation may not be completely extricable from the intentions of the participant (10). Folk *et al.,* (11) proposed that capturing attention in cueing paradigms depends on the top-down nature of the attentional control settings. Their studies showed that participants' attentions were captured if they were cued with coloured targets whilst being instructed to look for coloured targets. Task-relevant characteristics influence cue selection based on relevancy. Ansorge and Neuman (2) displayed a horizontal array of two boxes. In their task, the fixation screen was followed by unconscious primes on either side. Participants had to look for targets based on colour and provide a response. Priming effects were observed when the primes were relevant in terms of colour. Building on the work of Folk *et al.,* (11), Ansorge *et al.,* (1) proposed that subliminal cueing depends on top-down influences and task goals. This is bolstered by EEG N2pc recordings. However, they used only target-matching cues; therefore, the conclusions about the effectiveness of top-down contingencies are questionable. Subsequent research by Fuchs and Ansorge (3) also reinstates the idea that top-down settings influence attention capture through neuroscientific exploration of superior-colliculi mechanisms. In the target-absent condition, the distractors are also not displayed; therefore, this flaw leads to doubts over the robustness of the data and corresponding conclusions. The processing of subliminal cues in the context of valid and invalid cues with different levels of task-relevancy in both valid and invalid cues had not been studied before. In terms of cue characteristics, the present discussion has revolved around target matching and non-matching. In combination with cue validity, the relationship between feature match and attention capture becomes more complex. Supraliminal cueing studies have demonstrated the *same location cost (SLC)* effect (12), where valid cues with non-matching features lead to greater inhibition than invalid non-matching cues. In a challenge to the object-filing hypothesis posited by Lamy *et al*., (12) as an explanation for the effect, Schoeberl *et al*., (13) display the possibility of attentional mechanisms underlying same-location costs. The possibility of SLC in subliminal cueing may throw light on the attentional mechanisms involved in the cost. There is confusing evidence regarding top-down and bottom-up processing of subliminal cues. In contrast to some studies (3) that show no attention capture effects of non-matching valid cues, Schoeberl *et al*., (5) have shown evidence 'purely' stimulus-driven attentional capture effects of subliminal cues. Therefore, a reconciliatory understanding is essential to understand the purely bottom-up and top-down contingent processing in one experimental space. Further, previous studies have considered the top-down contingent of attentional control in terms of subliminal selection of cues and not feature processing with respect to valid but irrelevant feature matching of cues. Thus, the implications of this processing in the context of same-location costs can imply unconscious attentional effects removed from working memory as insinuated in the object-filing hypothesis. In the present study, task relevancy was the predominant top-down variable. Levels were constructed by manipulating the level of task relevancy of cues. The cues were of three types – i) Complete no-match, where the cue was a circle and the target was a coloured Landolt ring with four different orientations; ii) Incorrect colour match, where the

cue matches the shape of the target, but the colour is incorrect; 3) Full match, where the cue matches the shape, colour and even the orientation of the target making it the most task-relevant of all. Notably, most studies employed a stimulus presentation strategy where the stimuli were horizontally presented. In the present study, the stimuli were presented in a manner that required horizontal and vertical oculomotor behaviour. Further, due to the COVID-19 pandemic, the study was presented online instead of a controlled laboratory setting other studies have employed.

Considering existing research, the following questions were elicited – i) How much of a difference does task-relevancy elicit in both valid and invalid subliminal cueing conditions ii) Does subliminal processing of cues lead to same-location costs? The primary objective of this research was to bridge the understanding between bottom-up and top-down processes in subliminal cueing in one single paradigm and explore whether differences are elicited in attentional capture time. The secondary objective of this study was to explore whether incorrect match cues can lead to same-location costs when cues are subliminal. A tertiary objective was to reiterate different top-down and bottom-up mechanisms underlying supraliminal and subliminal visual attention processing in one paradigm (Figure 1).

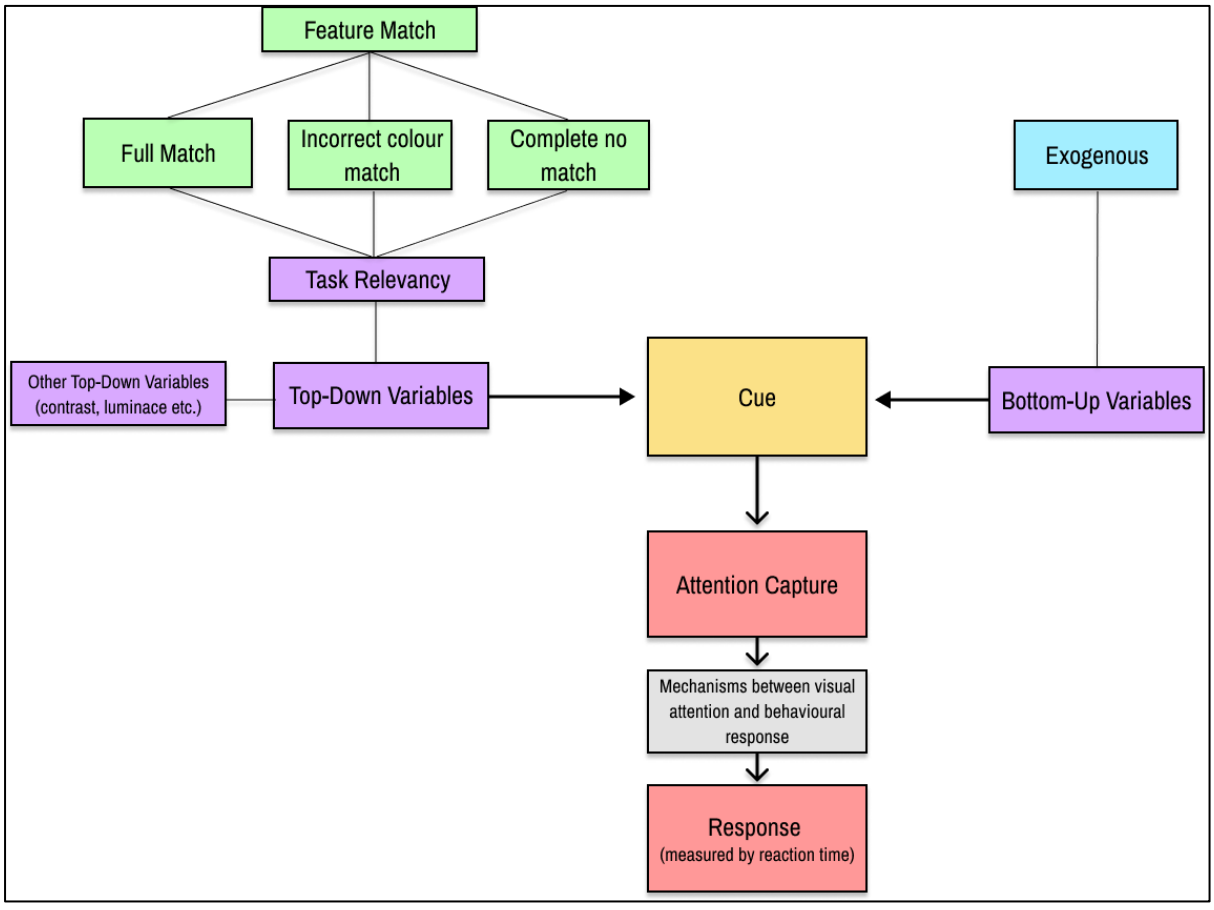

Figure 1: Top-down and Bottom-up Variables of Cues-conceptual Framework

Methodology

Sample

The study received 45 participants (24 females) sampled using a purposive snowball method. Out of the recruited participants, the data of three participants had to be excluded due to inattention during task performance. Forty-one participants (21 females and males) were considered for final analysis. The participants fell between 18 and 25 years of age, all of whom were college students residing in various parts of India (Table 1).

Table 1: Inclusion and Exclusion Criteria for Sample

Inclusion Criteria	Exclusion Criteria
Normal or corrected to normal vision	Colour blindness
Age between 18-23	Current diagnosis with or without treatment for any mood related disorders (depression, bipolar type I and II etc.)
	Prior, current or in remission diagnosis with/without treatment for any condition with psychosis (psychotic disorder, schizophrenia etc.)
	Prior or current diagnosis of Attention Deficit/Hyperactivity Disorder
	Diagnosed of other conditions that may affect attention (such as autism, Intellectual Disability)

Research Design

Participants went through conditions that were based on multiple combinations of validity, liminality and feature-matching. The study followed a within-group repeated measures design. Two levels of liminality (subliminal and supraliminal), two levels of validity (valid and invalid) and three levels of feature-matching (No-match, incorrect colour match and full match) rendered a 2x2x3 factorial (Table 2). This resulted in 12 conditions excluding an additional condition outside the factorial – no cue.

Table 2: 2x2x3 Factorial Design

	Supraliminal	Subliminal
Valid	Feature – No, incorrect colour match, Full match	Feature – No, incorrect colour match, Full match
Invalid	Feature – No, incorrect colour match, Full match	Feature – No, incorrect colour match, Full match

Note. An additional condition, "No Cue", exists outside the factorial.

Tools: Pre-requisite tools: As the study was conducted online, the following pre-requisites were conveyed to the participants prior to sending the study link. The participants had to ensure participation on any computer with a minimum of Intel Pentium @2.4 GHz, its equivalent or higher. A screen refresh rate of 60Hz with a 1980x1080 aspect ratio. With a minimum of 150 units of brightness and 71% sRGB colour gamut to ensure accurate colour reproduction which is necessary for the task. Monitor with an LCD/LED panel to ensure high viewing angles. The task was built using the jsPsych library (14) and was hosted online on cognition run. The task would run on any internet browser.

Task Structure: For the current study, a novel task based on the task used by Schoeberl *et al*., (5) was developed. The target discrimination experiment consisted of trials with five frames. The first frame was a fixation screen with a fixation cross. Then a blank screen was displayed for 700ms, followed by the cueing frame. For subliminal conditions, the cueing frame was displayed for 16ms, and for supraliminal conditions, the cueing frame was displayed for 700ms. This was followed by the discrimination frame, where four singletons were placed in four locations, north, east, south, and west from the center. Each singleton was an amalgamation of a placeholder (black circle) and a Landolt ring which was coloured. There were four colours of Landolt rings (red, green, blue, and yellow) with four different orientations. The orientations were randomized in each trial to maintain novelty and mitigate learning effects that can become a top-down confound.

In valid cue conditions, the cues were provided at the correct location of the target stimulus, whereas in invalid conditions, the cues were provided at the incorrect location. In no-match conditions, the cue was only a black placeholder. In incorrect match conditions, the Landolt rings were included; however, the colour did not match the target's colour. In full-match conditions, the placeholder and Landolt rings were presented where the

Landolt rings match the orientation as well as the colour. The participants were to indicate the position of the target stimulus using the 'W', 'A', 'S', and 'D' keys. 'W' indicated north, 'D' indicated east, 'A' indicated west, 'S' indicated south (Figure 2).

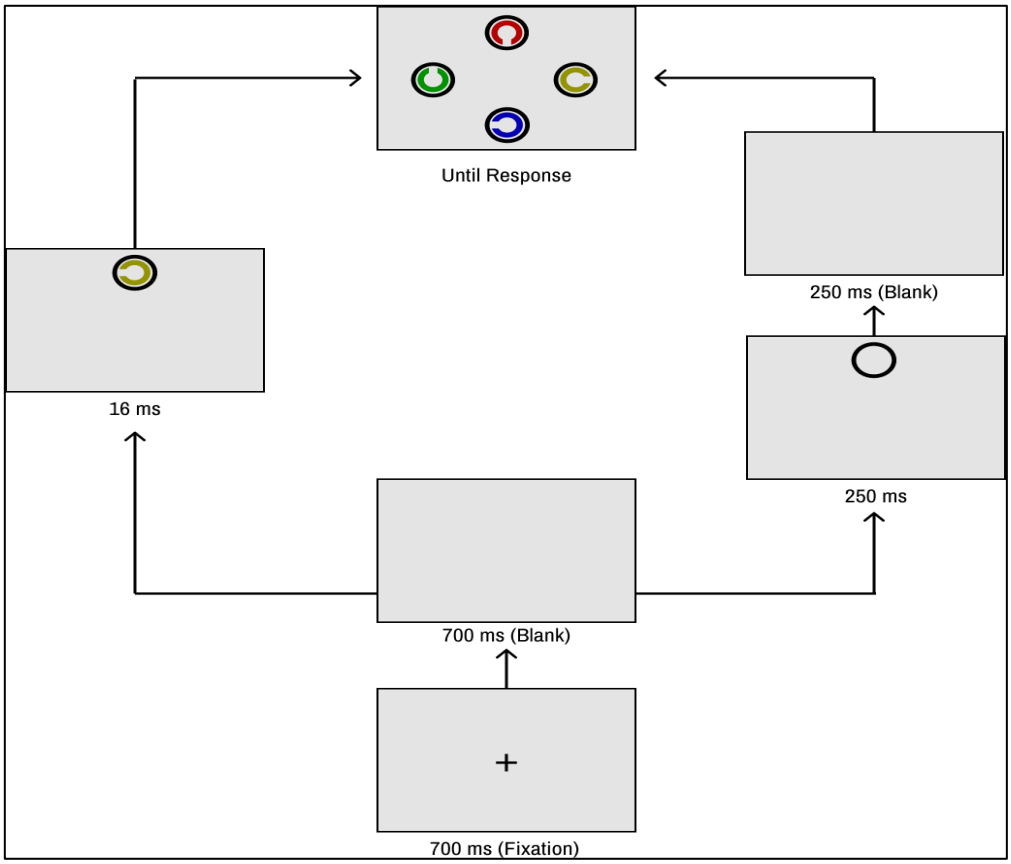

Figure 2: Trial Structure

Procedure

Upon opening the online link, an informed consent form was displayed. The consent form did not contain information regarding subliminal cues as it could have distorted the task performance. The participants filled the demographic sheet, and the screening tool. They were requested to be seated comfortably in front of the computer screen.

The task had two blocks with seven conditions each (no cue condition was repeated across blocks). The two blocks were divided based on liminality. In each blocks, the conditions were pseudo-randomized. Approximately after every 20 trials or so, the target was changed. Valid full-match conditions were presented for 58 trials resulting in a total of 116 trials across the blocks. Valid no-match conditions were presented for 34 trials resulting in a total of 68. Valid incorrect match trials were presented for 10 trials resulting in a total of 20 trials across blocks. All invalid conditions were presented for 5 trials each resulting in 30 trials (5x6) (~11% of total trials). Including 20 trials of no cues in both blocks (40 in total), the total number of trials rose to 274. On average, the task took 10-15 mins to complete depending on the average response time of each participant. After the task was completed, a subjective test of sub-liminality was conducted. Finally, a debriefing was done to inform the participants of all the variables involved in the study.

Method of Analysis

Preliminary Analysis: For every participant, the mean reaction time in each condition was analyzed using MS Excel. Outlier reaction times were excluded from the analysis. Initially, the standard deviation method (+2SD or -2SD) and the interquartile range method (mean*1.5IQR) was tested, and both yielded similar results. The total amount of trials excluded as part of outlier removal ranged from 1% to 13% across participants, depending on their consistency and attention levels. A few participants' data were excluded from the analysis as they had too many inconsistencies in their reaction time or too many outlier trials. Additionally, some participants made too many

accuracy errors as they followed the wrong target. If these errors and outlier analysis exceeded the threshold value of 20% on average across conditions, they were excluded. Based on these criteria, three participants were excluded from the analysis. The mean value of each trial condition was entered into jamovi (The jamovi project, 2021).

Secondary Analysis: A Shapiro-Wilks normality test was run, and normality could not be assumed for most conditions. Therefore, non-parametric statistics were employed. As this is a repeated measures design, Friedman and Wilcoxon's tests were used to test significant differences between conditions. A manual Bonferroni correction was done for the appropriate interpretation of significance levels. Facilitation and inhibition rates were analyzed using 'Mean differences' that indicate mean of differences between conditions rather than differences between the means.

Results

As the supraliminal block was presented after the subliminal block for all participants, it was important to check whether the lack of counterbalancing significantly affected baseline level reaction time. The median (IQR) values of no-cue subliminal and supraliminal were 471 [144] and 496 [166], respectively. A Wilcoxon signed-rank test did not reveal significant differences between the no-cue conditions in subliminal and supraliminal block (W=315, p=0.089). The results indicate a non-significant reduction in baseline level reaction time. However, the marginal reduction might have also been affected by the frame count in the no-cue presentation of the supraliminal block.

The repeated measures task can lead to practice effects or fatigue effects that may decrease or increase reaction time with successive trials. As the trials were pseudo-randomized, a higher proportion of valid full-match trials were presented towards the end of a block. A Wilcoxons' test was run to analyze differences between no-cue conditions in the first and the second half of the subliminal block. The test revealed non-significant differences between the no-cue conditions in the first and second half (W=534, p = .309). This indicated that, on average, there was no significant increase or decrease in reaction time across blocks.

Subliminal Block

A Friedman test revealed statistically significant differences in reaction times of multiple combinations of cue validity and feature-match in subliminal cueing conditions, $\chi2(5) = 82.4$, $p<.001$. Therefore, the first hypothesis was rejected. Wilcoxon signed-rank tests were conducted for pairwise comparisons. Median (IQR) reaction time for the no-cue, valid no-match, valid full-match and valid incorrect match trials were 471(144), 446 (155), 429 (127) and 458 (129) respectively. There were significant differences in reaction time between the no-cue condition and valid no-match condition (W = 884.0, p<.001). Significant differences were also observed between no-cue and valid full match conditions (W = 903.0, p<.001).

There were statistically significant differences in reaction time between valid incorrect and no-cue conditions (W = 822.0, p<.001). These comparisons indicate that all valid cues led to attention capture facilitation regardless of top-down variables. Pairwise comparisons did not reveal statistically significant differences in reaction time between any invalid cue condition and the no-cue conditions (Figure 3).

A Friedman test revealed significant effects of task relevancy among subliminal valid cue conditions $\chi2(2) = 30.3$, $p<.001$. Wilcoxon signed-rank test between valid no-match and valid full match revealed significant differences in reaction time (W = 746, p<.001) where responses in valid full match were faster. Valid full match was also significantly different from valid incorrect (W = 40.5, p<.001) with a mean difference of -22.2. Valid no-match was significantly different from valid incorrect conditions (W = 260, p=.016).However, Bonferroni corrected alpha set considering the number of tests and initial alpha value is p = 0.008. Therefore, the significance of the difference between valid no-match and valid incorrect does not hold. A full match in terms of colour and shape led to significantly faster attention capture thereby indicating the role of task relevancy in subliminal processing of visual stimuli. Incorrect match led to weakest attention capture effects among the three valid conditions indicating relative costs but not absolute costs in facilitation. Therefore, hypothesis 2 was confirmed (Figure 4).

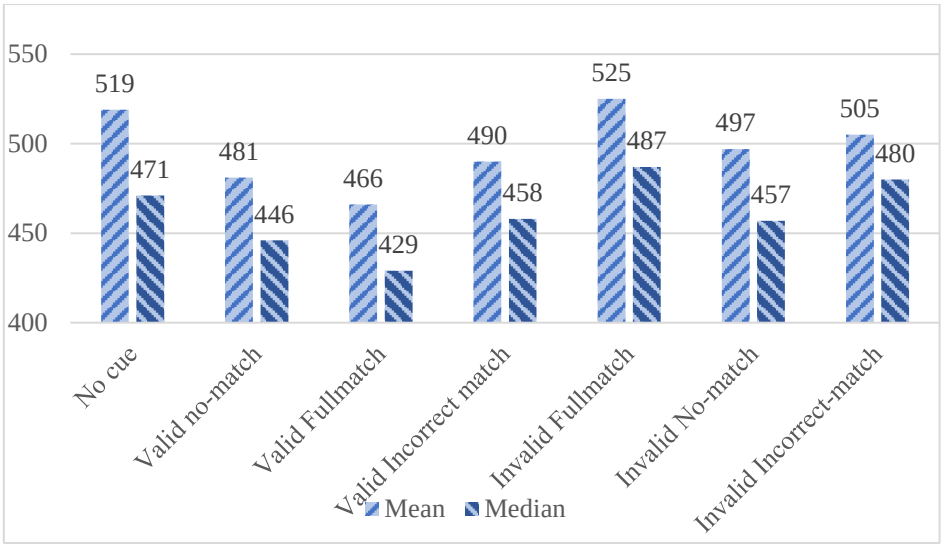

Figure 3: Means and Medians of all Conditions in the Subliminal Block

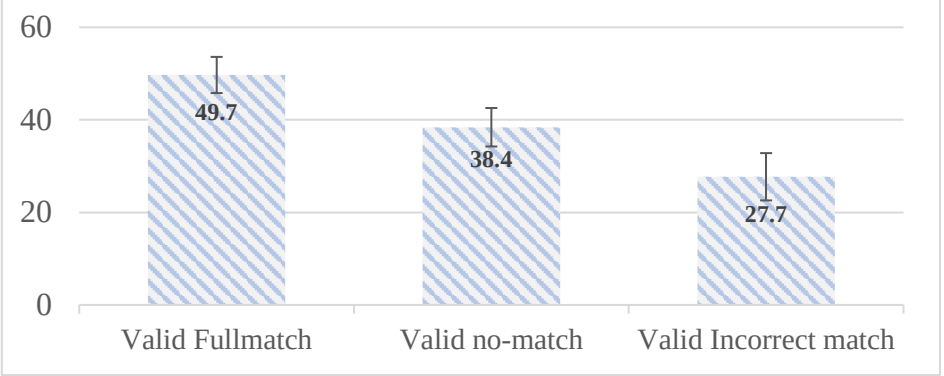

Figure 4: Mean Facilitation and Inhibition Rates of All Valid Conditions in the Subliminal Block (Note: *All mean of differences are calculated in relation to no-cue condition which indicates baseline reaction time. Positive values indicate facilitation*)

Supraliminal Block

A Friedman test revealed statistically significant differences in reaction times of multiple combinations of cue validity and feature - match in supraliminal cueing conditions, $\chi2(5) = 154$, $p<.001$. Wilcoxon signed-rank tests were conducted for pairwise comparisons. Median (IQR) reaction time for the no-cue, valid no-match, valid full-match and valid incorrect match trials were 496 [166], 448 [144], 362 [80.1] and 533 [172] respectively. There were significant differences in reactions between the no-cue condition and valid no-match condition (W= 898.0, p<.001). Significant differences were also observed between no-cue and valid full match conditions (W = 903.0, p<.001). There were statistically significant differences in reaction time between no-cue and valid incorrect conditions (W = 173.0, p<.001) where reaction times valid-incorrect condition was significantly slower (mean difference = -27.0). Therefore, benefits of validity were observed in valid full match and no match conditions and same-location costs were observed for valid incorrect cues (Figure 5).

Task relevancy had a significant effect on reaction times of all valid cues as indicated by a Friedman test $\chi2(2) = 78.1$, $p<.001$. Similarly, there was a significant of task relevancy on reaction times of all invalid cue conditions as well $\chi2(2) = 33.0$, $p<0.001$. Wilcoxon signed-rank test between valid no-match and valid full match revealed significant differences in reaction time (W = 901.0, p<.001) where responses in valid full match were faster (mean difference = 84.8).

Valid no-match was significantly different from valid incorrect conditions (W = 893, p<.001) where valid no-match was faster (mean difference = 79.6). Therefore, task relevancy, where the cue colour matches the target colour, showed significantly faster attention capture effect (Figure 6).

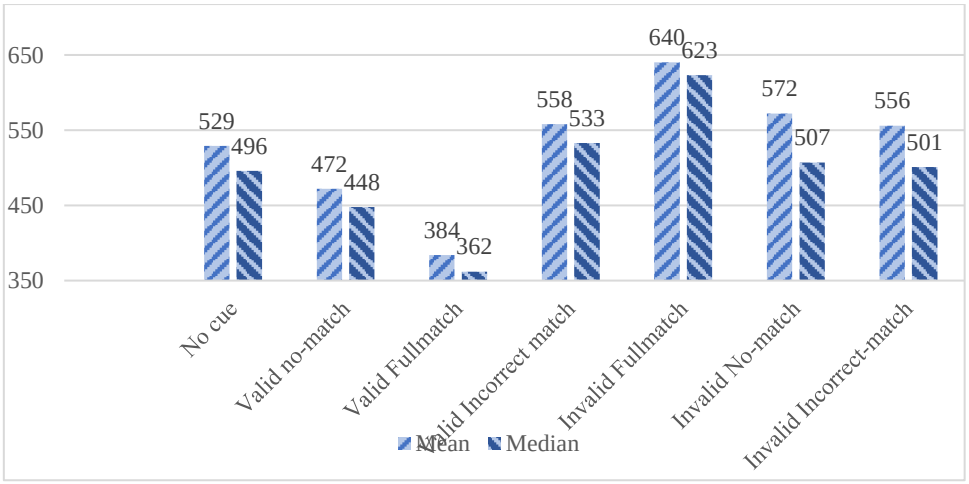

Figure 5: Means and Medians of All Conditions in the Supraliminal Block

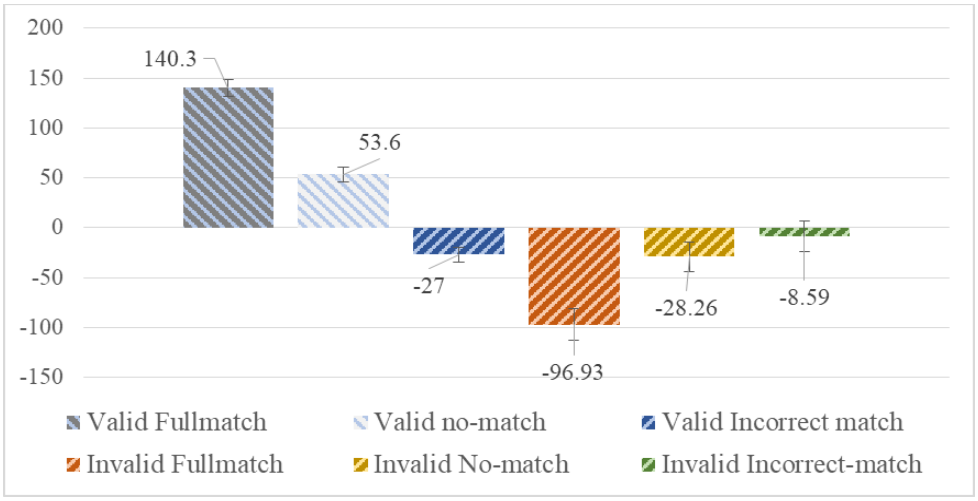

Figure 6: Mean Facilitation and Inhibition Rates (Mean Differences) of All Conditions in the Supraliminal Block (*Note: Positive values indicate facilitation and negative values indicate inhibition of attention capture*)

In comparison to no-cue conditions there were significant differences in reaction time in invalid full-match (W = 7.00, p<.001) and invalid no-match (W = 222.0, p<.001) conditions, where both conditions showed an increase in median reaction times. However, there were no significant differences between no-cue and invalid incorrect trials (W = 320.0, p=.156). Invalid full-match and invalid no-match displayed significantly different median reaction time (W = 716.0, p<.001) where invalid full-match showed an increase in reaction times (mean difference = 66.61). There was no significant difference between invalid no match trials and valid incorrect trials (W=470.0, p=.824).

Discussion

Cueing was effective in capturing attention in subliminal conditions. All valid cue conditions irrespective of top-down effects were able to decrease reaction time successfully. These points towards the stimulus-driven nature of attention capture with exogenous cues. Similar to findings by Schoeberl *et al.,* (5), a cue without task-relevant top-down variables captured attention effectively. A feature and colour match (full-match) was most effective in capturing attention in comparison to no-match and incorrect match conditions. This indicates that task-relevancy had a significant effect on attention capture when cues were presented subliminally. The valid incorrect match cueing condition displayed the weakest attention capture effects in comparison to other valid cue conditions. Same-locations costs were not observed in the subliminal cue conditions. In line with existing literature, invalid trials in subliminal cueing conditions did not significantly affect attention capture. This holds irrespective of the levels of top-down characteristics of the cue. Therefore, subliminal attention capture seems to show independent mechanisms for facilitation and inhibition of attention.

In the supraliminal block, same-location costs were observed. As observed by Lamy *et al.,* (12), conscious perception of stimuli influences same-location costs. However, the marginal but significant (in comparison to task-relevant cues) increase in reaction time of valid subliminal cues with task-irrelevant colour implies the possibility of some attentional mechanisms involved with same-location costs (13). The effects of the cues were different in subliminal and supraliminal blocks. Due to the lack of statistical normality in the data and the concurrent use of non-parametric statistics, it was not possible to derive robust conclusions with absolute differences in values. Generally, the facilitation rates were almost double in the supraliminal block. Invalid subliminal cues did not inhibit attention capture. However, invalid supraliminal cues were able to inhibit attention capture. In both blocks, task-relevant cues were more effective in capturing attention. In the supraliminal block, the inhibition rates of invalid feature-match cues were significantly greater than no-feature-match invalid cues, indicating the role of task-relevancy in inhibition when cues are above the threshold of consciousness. Interestingly, valid incorrect feature match trials showed same-location costs. However, when these cues were invalid, there was no significant inhibition or facilitation. These points towards top-down processing where task-irrelevant cues were not considered or probably 'ignored'. The present study exhibits greater mean differences than other studies of a similar nature (2, 4, 5, 7). This may be due to factors apart from the elephant in the room - the lack of normality in the data set. Firstly, a target detection task was used instead of a target discrimination task, unlike Schoeberl *et al.,* (5). Secondly, the keys used were 'W, A, S, D', which are standard keys used for gaming using a keyboard. Most participants in the study have had experience playing games using their keyboards. This is unlike the other studies reviewed here, where a new set of relatively unfamiliar keys had to be used. Thirdly, the cue presentations were not entirely peripheral. The saccades of the participants were not monitored to maintain fixation at the centre point. Therefore, there was a high reliance on the fixation cross. Fourthly, the 16ms presentation of cues may have varied due to differences in the processing speed of computers and browsers. Finally, unlike some studies (12, 5), the cues were viewed with both eyes. The online presentation of this experiment meant a lack of traditional experimental controls. There was no standardization in an angle of presentation, seating position, screen characteristics (size, brightness, colour gamut etc.), the brightness of the room, potentially distractors in the environment, or computer processing speed (which can affect presentation speed), among many others. It must be noted that these instructions were given. However, likely, some of them were not followed strictly. These tool-related problems are limitations that can, however, be phrased as a strength from an 'applied' or 'effectiveness' framework. There was no chance to adjust subjective luminance to correct for background colour contrast effects based on individual differences. This entails the possibility of top-down variables trickling into stimulus-driven cue trials. Therefore, the non-feature matching cue might not have been 'purely' stimulus-driven. The number of trials was reduced to make it viable for online presentation. This consequently reduced the number of invalid trials, which made for difficult statistical analyses as a few errors in those conditions would render the mean of the data unusable. Further, the number of valid cues with incorrect feature-match trials was also reduced as they were perceived as 'incorrect' cues in the pilot study. Therefore, it is recommended that a follow-up is done with more trials, especially in the invalid conditions. The dependent variable here – reaction time – involves attention, decision, motor planning, and execution, among other processes. Behavioural data might not be enough to extract information about visual attention. We cannot say for sure that the effects of exogenous cues are 'caused' due to attention alone. Concurrently, there is a lack of clarity regarding the 'location' of inhibition and facilitation in the processes between attention and response. For example, Van der Stigchel *et al.,* (15) indicate that subliminal stimuli affect oculomotor behaviour. However, this was not verified in the current paradigm. Incorrect feature match supraliminal cues were likely to have been deemed as task irrelevant. It is conjectured that the participants might have viewed the cues with a bias towards validity as it was explicitly primed to them with instructions, and subsequently, the stimuli presentation represented the same. With this bias,

the spatial location of incorrect matching cues might also be deemed irrelevant and may consequently have been 'ignored' in a top-down fashion. This explains the inhibition effect of valid incorrect cues. However, pure ignorance of the location would mean visual scanning should have occurred for 3/4 of the stimuli displayed. Either there is no significant difference between scanning for three or four of the stimuli, or there are unexplained factors affecting facilitation in this context. Further, the invalid cue did not match the features of the distractor at least two-thirds of the time. Logically, a working memory updating process must have occurred as there is an entirely different percept within a span of 250ms. Therefore, there is a need to evaluate the object-filing hypothesis in this respect more rigorously and thoroughly.

The findings of the paper show that attention can be captured exogenously without the awareness of the individual. The paper also exhibits the superior attention capture effects of cues that match the target completely in terms of characteristics. The findings of the paper may be useful in educational settings. It may be useful for computerized cognitive training, specifically for disorders that presents with significant attentional problems as part of their symptomology. The findings may also be useful in advertising and marketing to orient the audience's attention towards pre-determined areas.

Conclusion

A target discrimination paradigm adapted from Schoeberl's and modified to account for vertical coulometer rotations. The task was presented online. Task-relevant cues elicited superior attention capture effects as compared to task-irrelevant cues in both subliminal and supraliminal cuing conditions. Irrespective of task relevancy, all valid cues exhibited attention capture effects in subliminal cuing conditions. In contrast to supraliminal cues, invalid subliminal cues did not exhibit inhibitory effects on attention. Task-relevant invalid cues were more potent in producing inhibitory effects. Valid cues with incorrect feature-match in relation to the target stimuli were less effective in attention capture as compared to feature-matching and no feature-match cues in subliminal conditions. Attention facilitation and inhibition may have different mechanisms. The inhibitory mechanism is different in subliminal and supraliminal conditions implicating the role of consciousness. Finally, the paper discussed major limitations in the methodology and theoretical implications of the findings.

Abbreviations

Nil.

Acknowledgement

Nil.

Author Contributions

Shreyas Krishnakumar: Conceptualization, methodology, software, validation, formal analysis; Maharishi Ranganathan: investigation, resources, data curation, writing original draft preparation, supervision; Ganesh Kumar: writing, review and editing, supervision; Parveen Banu R: Data analysis, review and editing, supervision: Annapally, Sadananda Reddy: Data analysis, review and editing, supervision.

Conflict of Interest

The authors declare that there is no conflict of interest.

Ethics Approval

Ethical review and approval by IRB of Institution. Informed consent was obtained from all the participants and the participant data has been fully anonymized. Ethical Approval Number: CU: RCEC/95/07/22.

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