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CHAPTER 6

Interdependence of attention and consciousness

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Abstract: Research on attention has been closely linked with possible advances in the study of consciousness. Various theories and models have been proposed for attention in the past 50 years. Behavioural, computational, and neuroscientfic approaches have been successful in improving our understanding of attentional processes. Given the current status of attention research, what can we say about the relationship between attention and consciousness? This paper discusses the possible relationships between attention and consciousness. Findings from cognitive science and neuroscience relevant to the elucidation of this relationship are discussed. Recent findings from phenomena that have a bearing on this relationship such as inattentional amnesia, change blindness, attentional blink, perceptual stabilization, and afterimages are described. The implications of the results of these phenomena for attention and awareness are also discussed. It is proposed that top-down attention is not a unitary phenomena and such a characterization may provide a way to interpret some of the results from these findings.

Keywords: attention; consciousness; perception; selective attention; change blindness; attentional blink; inattentional blindness

Introduction

Attention is not a unitary process. Different types of attentional processes include processes like selective attention and vigilance. Selective attention itself is thought of in terms of the basis on which selection is made (location, feature, or object). The most typical way attention is visualized is as a process of selecting information from the visual field for further processing. Various metaphors have been proposed to describe this selective nature of processing including spotlight (Posner, 1980) and zoom lens (Eriksen and Yeh, 1985). Directing attention to a particular location or object typically enhances information processing at that location or for that object. The changes in processing due to attentional processes may be accompanied by eye movements which is called overt attention or may not involve any eye movements which is called covert attention. Cueing paradigms are commonly used in studies based on orienting of attention or spatial attention (Posner, 1980; Posner and Cohen, 1984). A typical cuing paradigm involves participants fixating on a central point and then directing attention to either the left visual field (LVF) or right visual field (RVF) when the central fixation is replaced by left or right directing cues. The participants respond to the targets presented at the cued or uncued locations. There are two types of cueing: exogenous and endogenous. Exogenous cueing or reflexive orienting is involuntary in nature and depends on the properties of objects in space.

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Exogenous cueing effects reveal themselves even when reflexive eye-movements are suppressed. Attention moves reflexively to the place of onset or offset of the stimulus in space over time. Many studies have shown that a valid peripheral cue facilitates target detection. The cueing effect is found to be large when the stimulus onset asynchrony is around 100–200 ms (Muller and Rabbitt, 1989). At large SOAs, performance at invalidly cued locations is better than validly cued locations, which has been termed the inhibition of return (Posner and Cohen, 1984). Unlike exogenous or peripheral cuing, typical endogenous cuing utilizes a symbolic cue and attention is shifted voluntarily to the cued location. While voluntary attention results in better performance, it also differs from the processes involved in stimulus-driven attention.

A way in which attentional processes have been characterized is the stage at which selection occurs. Early selection theories proposed by Broadbent (1958) argue that selection occurs at an early stage in perceptual processing. Late selection theories argue that selection occurs after identification of stimuli and is usually thought of in terms of response selection (Deutsch and Deutsch, 1963). Intermediate views on the stage at which selection occurs have also been proposed (Treisman, 1960). Both behavioral and electrophysiological evidence have been used to argue for or against these different views on attention. The majority of attention theorists seem to tend towards early selection theories while accepting that selection occurs at late stages as well including at the level of a response. This chapter mainly focuses on selective aspects of attention.

Studies based on visual search by Triesman and others (Treisman and Gelade, 1980) has led to a two-stage model consisting of a preattentive stage and an attentive stage. Preattentive processing can be defined as quick and basic feature analysis of the visual field, on which attention can subsequently operate. These basic featural computations are combined through the process of spatial attention which is called the binding problem (Treisman and Gelade, 1980). Binding is also necessary for having a unitary conscious experience pointing to the strong relationship between attention and consciousness.

Similar to research on the mechanisms involved in attention, consciousness research has been flourishing in the past 20 years. Reflecting the different views on consciousness, a number of definitions of consciousness have been proposed. Typically awareness is considered a main characteristic of consciousness and it is awareness that will be mainly discussed in this chapter. This includes subjective awareness of the environment (external) and of one's own mental processes (internal). Different characterizations or distinctions have been proposed for studying consciousness. One way in which consciousness has been characterized is in terms of primary consciousness and access consciousness (Block, 2005). Primary consciousness refers to the phenomenal aspects of experience, i.e. qualia. Access consciousness refers to the functional aspects of consciousness which is related to cognitive processes like executive attention, planning, and voluntary control. Essential aspects of consciousness as awareness include its subjective nature and reportability. In most of the studies, the report of participants as "aware" of a particular stimulus is taken as evidence for participant's awareness of the stimulus.

Different views have been proposed on consciousness in terms of its psychological as well as neural underpinnings. For example, consciousness has been visualized as a global work space (Baars, 1997, 2005). According to global workspace theory, unconscious systems process information in parallel and these are made available for access to all the processing systems through the global workspace or a theater. Some have argued against the notion of a Cartesian theater (Dennett, 1991). Dennett (1991) has proposed a multiple drafts model of consciousness in which there is no specific place where everything comes together. On a related line, Zeki (2003) has argued that consciousness of a particular feature is dependent on activation of the extra striate area that specializes in the processing of that feature. Activation of an area will result in a "microconsciousness" of that feature.

One approach to study consciousness has been to look for the neural correlates of consciousness (NCC) by Koch and his colleagues (Crick and Koch, 2003; Koch, 2004). NCC has been defined as the "minimal set of neuronal mechanisms or

events jointly sufficient for any one specific conscious percept or experience'' (Koch, 2004). NCC has been studied by keeping the visual input constant and studying dynamic changes in awareness or visibility of a stimulus. The study of NCC tries to identify neural activity accompanied by awareness and neural activity that is not accompanied by awareness. Within 120 ms of the stimulus presentation, most areas are activated in essentially a feed forward manner and later activations are dependent on recurrent activations. It has been argued that such recurrent activity is necessary for consciousness (Lamme, 2003). On the lines of the distinction proposed by Block (2005), primary awareness is argued to be due to recurrent activations in early perceptual areas and access consciousness is argued to be due to activations in higher centers like prefrontal cortex. Given this brief overview of attention and consciousness, we move on to a discussion on linkages between these two important concepts.

Relationship between attention and consciousness

The relationship between attention and consciousness has been debated for a long time. One of the most quoted definitions of attention, ''Every one knows what attention is. It is the taking possession of the mind, in clear and vivid form, of one out of what seem several simultaneously possible objects or trains of thought. Focalization, concentration of consciousness are of its essence. It implies withdrawal from some things in order to deal effectively with others, and is a condition which has a real opposite in the confused, dazed, scatterbrain state'' (James, 1890/1950) makes a strong connection between the two concepts. Views that emphasize the close relationship between attention and consciousness are common (Posner, 1994). According to this view, what is attended and what is conscious are one and the same or at least closely coupled.

One of the most compelling set of studies that provided evidence for this close link came from the studies on inattentional blindness (Mack and Rock, 1998). They proposed the concept of ''Inattentional blindness'' to explain failure in detection of unattended stimuli. Their hypothesis is that we do not consciously perceive objects which we have not attended. In their experiment, observers were briefly presented a cross, whose vertical and horizontal component differed slightly in length. Observers were asked to judge whether the vertical or horizontal component of it is longer. In one of the trials an irrelevant stimulus was flashed in one of the quadrants formed by the cross. After the trial, observers were asked if they saw anything out of the ordinary. With their attention focused on the discrimination task, a large number of observers failed to notice the target stimulus. Around 25% of participants said that they did not notice the unexpected stimulus that appeared parafoveally and the cross was presented at fixation. Interestingly around 75% of the participants reported not perceiving the target stimulus that appeared at fixation with the cross presented parafoveally. Observers failed to report the irrelevant stimulus when they were not aware that such a stimulus might appear, although the normally irrelevant stimulus was easily visible. Mack and Rock (1998) argued that in the absence of attention, the irrelevant stimuli never rose to the level of conscious perception.

The inattentional blindness argument is used to explain the failure of change detection in several change blindness (CB) experiments (Grimes, 1996). Grimes (1996), in his experiment, tracked observers' eye movements while they viewed scenes for 10 s, in a change detection experiment. Scenes were altered during eye movements, and a single object was changed either in size, color, or location or they could disappear. Observers failed to detect these changes and inattentional blindness argues that the changes are not seen because the changed object was not attended and thus not consciously perceived. However, inattentional blindness fails to explain convincingly results of Simons and Levin (1997) or Rensink et al. (1997) experiments in which stimuli is presented for a very long time. In their CB experiments observers may have attended to the object and yet not detected changes to them. CB is the phenomena where we fail to perceive large changes, in our surroundings as well as in experimental conditions. Change could be in existence, properties, semantic identity, and spatial layout. Attention is required to perceive change,

and in the absence of localized transient motion signals (that may attract or grab attention), attention is directed by high level of interest (Rensink et al., 1997). Only when attention is focused on an object, can change in the object be perceived. The contents of visual short-term memory are simply over written with succeeding stimuli without focused attention (Rensink, 2002). Studies do show that more information is available than what is consciously available for report. For example, it has been shown that localization was above chance level even in undetected trials (Fernandez-Duque and Thornton, 2000). In addition, response times are longer in failed change detection trials in which change actually occurred (Williams and Simons, 2000). Change detection has been shown for changes in the background (Driver et al., 2001). More interesting are claims of blindsight in which observers claimed to sense the change before they were aware of the change suggesting that sensing occurs due to conscious non-visual awareness (Rensink, 2004).

A slightly different perspective on the close relationship between attention and consciousness is provided by studies in which load was manipulated and awareness of stimuli were evaluated (Cartwright-Finch and Lavie, 2006; Lavie, 2006). One was an inattentional blindness task in which the primary task was easier (low load) or difficult (high load). They found that inattentional blindness was more in the high-load condition compared to the low-load condition (Lavie, 2006). They also performed a change detection study in which the primary task (low load or high load) was presented at fixation and change between two scenes had to be detected at peripheral locations. Once again, change detection was better in the low-load condition compared to the high-load condition indicating that focused attention is necessary and plays a critical role in awareness (Lavie, 2006). In addition to better performance, a recent study has shown that attention can alter phenomenal appearance (Carrasco et al., 2004). They showed that the contrast of an attended (using an exogenous cue) grating was higher than the contrast of the unattended grating.

While acknowledging the close relationship between attention and consciousness, a large number of recent studies have convincingly argued that attention is different from consciousness (LaBerge, 1995; Baars, 1997; Hardcastle, 1997; Beilock et al., 2002; Naccache et al., 2002; Crick and Koch, 2003; Lamme, 2003; Woodman and Luck, 2003; Kentridge et al., 2004). According to Lamme (2003), consciousness operates prior to attention. Attentional selection operates on conscious stimuli leading to verbal report or store for later conscious, typically verbal access. Unconscious stimuli are outside the control of attention.

According to Dehaene et al. (2006), consciousness and top-down attention can be thought of in terms of a 2×2 matrix in which one of the dimensions is bottom-up stimulus strength (weak or sufficiently strong) and the other is top-down attention (absent or present). They ended with four classes of processing: subliminal-unattended, subliminal-attended, preconscious, and conscious. These different types of processes are sub served by different neural networks. Conscious processing refers to the case in which stimulus strength is high and top-down attention is present. This class is characterized by reportability, intense activation, and long-range interaction across cortical areas. The subliminal (unattended) is characterized by absence of priming and is not affected by top-down attention. These processes are also characterized as essentially feed-forward processes in the brain. Unlike the subliminal (unattended) processes, the processes in the other subliminal class are supposed to show stronger activation and short-term priming. Both the subliminal classes of processes are not associated with reportability. The preconscious, mainly sensorimotor in nature, display priming effects and are also not reportable in the absence of top-down attention. They also argue that global synchronization is characteristic of conscious processes and local synchronization is characteristic of preconscious processes.

Koch and Tsuchiya (2007) have proposed a fourfold classification scheme in which attention and consciousness are different. Certain processes are analyzed in terms of whether is attention necessary or not and whether they may give rise to consciousness resulting in a 2×2 matrix of possibilities. Some processes like early rapid vision does not need attention and may not give rise to

consciousness. This will also cover a significant amount unconscious information processing. Some processes may need attention and will give rise to consciousness. Some processes like priming and thoughts may require attention and may not give rise to consciousness. It is quite possible that some processes benefit from attentional processing without the involvement of consciousness. The most interesting possibility is the case of processes for which attention is not required but gives rise to consciousness. In the context of the differing views on the relationship on attention and consciousness, questions can be raised on whether attention is necessary for consciousness and whether consciousness is necessary for attention.

Is consciousness necessary for attention?

If consciousness is necessary for attention, then it implies a view of attention as a process that operates on stimuli that are consciously perceived. This view of attention belongs to the late selection theories of attention (Deutsch and Deutsch, 1963; Neuman, 1987; Lamme, 2003) which typically argue that early perceptual processing until conscious identification does not have capacity limitations and the purpose of attention is selection of appropriate actions. Using findings from a change detection study (Landman et al., 2003), it has been argued that change detection performance is very high. In the study, an initial stimulus display consisting of eight rectangular bars (vertically or horizontally oriented) was followed by a blank screen and a subsequent stimulus (with or without change). They showed that change detection performance with a spatial cue during the blank interval was as good as the performance with a spatial cue presented with the initial stimulus display indicating that attention operates on items that are in working memory and are conscious for a short amount of time. However, using a similar paradigm manipulating both the number of items as well as the duration of blank interval, Naaz and Srinivasan (2005) have shown that the better performance shown in the Landman et al. (2003) study saturate and is also dependent on the duration of blank interval with better performance with a longer interval of 1500 ms. These results question the interpretation of results from change detection for arguing that attention operates on items that were conscious.

Results from other studies also question the hypothesis that consciousness is necessary for attention (He et al., 1996; Naccache et al., 2002; Kentridge et al., 2004; Jiang et al., 2006). Top-down influences of attention on subliminal processing question the position that attention operates on information available through consciousness. Subliminal priming is present under attention but not when attention is diverted (Naccache et al., 2002). In a study with the blindsight patient GY, Kentridge et al. (2004) showed that a conscious cue helps in the detection of unconscious stimuli in his blind visual field. A peripheral grating that is masked by other stimuli and is not consciously perceived never the less produce orientation specific after effects (He et al., 1996). Unconscious emotional information has also been shown to attract attention (Jiang et al., 2006). Pictures of nudes which were not seen however had an effect on ratings of attraction indicating that unconscious information can attract attention. These results suggest that attention can operate on essentially unconscious information.

Is attention necessary or sufficient for consciousness?

The strongest arguments for the necessity of attention for consciousness have been the findings from inattentional blindness (Mack and Rock, 1998) and CB studies (Rensink et al., 1997; Simons and Levin, 1997). As discussed earlier, stimuli that were not attended were not seen in studies on inattentional blindness (Mack and Rock, 1998). However, some stimuli were seen compared to others indicating that possibly salient stimuli can capture attention. While these findings strongly support the claim that attention is necessary for explicit reporting of stimuli or change in stimuli, attention might not be the only critical factor in conscious detection of stimuli. Simons and Levin (1997) in their experiment showed that change detection was poor even when the changed object

was attended. Forty observers were shown a movie clip in which a single actor was performing some actions. When the actor was switched across the camera positions, observers failed to notice the change. When observers were warned about the change, performance was better. It was concluded that object features do not integrate automatically to form different views of the scene.

Results of experiment by Mack and Rock (1998) were interpreted by Braun Julesz (1998) as an argument to support the view that attention is not sufficient to detect change. The failure of change detection in their experiment was due to lack of expectation rather than attention. Rensink et al. (1997) found in their study that changes to objects of central interest are easier to detect than changes to objects of marginal interest. This faster detection of change to objects of interest could be due to the fact that we are expecting change to significant objects of the stimulus. Simons and Levin (1998) found that people did not notice even when the person to whom they were talking was changed. This failure to detect change could be because of our expectation of a stable world. We do not expect people to suddenly change into someone else. These studies on inattentional blindness and CB suggest that blindness is more from the observer's inability to anticipate the stimulus than from lack of attention. Thus, it might be concluded that attending to an object is necessary but not sufficient for change detection.

Studies with different paradigms have been used to argue that attention may be neither necessary nor sufficient for consciousness. One paradigm that is commonly used is the rapid serial visual presentation (RSVP) paradigm. In this paradigm, targets are presented one at a time very briefly. Typically the presentation of the target as well as the blank interval has a duration of around 100 ms. Participants have to detect two targets (T1 and T2) and the rest of the stimuli are distractors. Target T1 appears first followed by target T2 and the temporal gap (lag) between T1 and T2 is varied. The basic finding is that accurate identification of target T2 is poor for lag 2, i.e. when there is one distractor presented between T1 and T2. This phenomenon is called attentional blink (Raymond et al., 1992; Chun and Potter, 1995). The performance improves with higher lag and reaches asymptote around lag 6 or 7. In attentional blink, participants attend to the stimuli but are still not able to consciously detect T2 indicating that attention may not be sufficient for consciousness. When participants were asked to rate T2 visibility on a continuous scale, conscious report of T2 was dependent on a threshold for visibility of T2, i.e. attentional blink results from an all or none process of conscious perception rather than a gradual one (Sergent et al., 2005).

It has been shown that the T2 performance improves in the AB task when a task-irrelevant mental activity is concurrently performed (Olivers and Nieuwenhuis, 2005). Some hypotheses have been investigated regarding the distracting tasks affecting performance on T2 (Olivers and Nieuwenhuis, 2005). The critical claim of the overinvestment hypothesis is that the processing interference in the second stage is a direct consequence of allocating too many attentional resources to the RSVP stream. Conversely, a reduction of the attentional focus (by a distracting task) limits the number of items that can access the second stage, which alleviates the amount of interference and reduces the probability of an AB. This may also be due to the positive affective states that are induced during the task performance that pulls away resources from the central RSVP task, resulting in reduced interference (Olivers and Nieuwenhuis, 2005). These findings and findings from other studies (Lou, 2001; Leopold et al., 2002; Li et al., 2002; Suzuki and Grabowcky, 2003; Dijksterhuis et al., 2006; Kanai and Verstraten, 2006) have been interpreted to indicate that attention and consciousness can oppose each other (Koch and Tsuchiya, 2007). It is important that these findings are critically analyzed to see whether such a conclusion is warranted.

In a study with afterimages (Suzuki and Grabowcky, 2003), two overlapping triangles with different colors were shown. Participants were asked to attend to one of the triangles and not attend to the other triangle. Afterimages were obtained with both the overlapping triangles (attended as well as unattended) but they differed in their onset as well as offset. The afterimage for the unattended triangle appeared first followed by the afterimage of the attended triangle. In addition,

the afterimage of the attended triangle is weaker and disappeared earlier than the unattended triangle. Attention does not produce early or stronger afterimages. In another experiment, participants either attended to the afterimage inducer or to a stream of letters. They found once again that afterimages appeared later when the afterimage inducer is attended compared to when the letter stream was attended. Suzuki and Grabowcky (2003) have argued that these findings imply that attention facilitates adaptation of polarity-independent processes rather than polarity-dependent processes in the visual system. It has been argued that polarity-independent processes affect the visibility of afterimages whereas polarity-dependent processes affect the formation of afterimages. Koch and Tsuchiya (2007) have argued that the results of Suzuki and Grabowcky (2003) imply that attention and awareness can oppose each other. Based on the interpretations of Suzuki and Grabowcky (2003), it is clear that it cannot be concluded that attention and awareness oppose each other. Weakened afterimages of attended stimuli might be necessary for clear awareness of subsequently attended stimuli. This can be likened to the phenomenon of inhibition of return in which previously attended locations are inhibited. In this case, the afterimage of previously attended stimulus is inhibited or weakened which should have a facilitatory effect on the awareness of the next to be attended stimulus.

Leopold et al. (2002) showed that a bistable figure like a Necker cube is stabilized (only one percept is continuously seen) if the figure is presented periodically with a blank screen between successive presentations of the figure (intermittent presentation). Attention has been shown to play a critical role in perceptual stabilization. Distracting attention during the blank interval interfered with the process of perceptual stabilization with stimuli in which the direction of motion was ambiguous (Kanai and Verstraten, 2006). They have argued that the implicit memory for the percept that is necessary for stabilization utilizes attentional resources. When subjects had to perform a dual task, stabilization decreased. Koch and Tsuchiya (2007) argue that this decrease in perceptual stabilization due to withdrawal of attention due to a dual task is evidence for opposite effects due to awareness and attention. Similar to the situation with afterimages, it is important to consider carefully the effects of attention and consciousness when multiple percepts are involved. Is stabilization evidence for enhancement or reduction of effects of awareness? Without understanding the role of "stabilization" which has been demonstrated with bistable stimuli in awareness or its interaction with attention, it is too early to conclude that these findings show that the effects of attention and awareness are opposite.

The role of attention was evaluated using a dual task which used a relatively difficult visual search task in which observers had to search for an odd element in an array of five randomly rotated Ls or Ts as well as a scene/object categorization task in conjunction with a primary task. It has been found that the gist of a scene is processed quickly. Apparently simple tasks like differentiating between rotated letter stimuli were more difficult to perform rather than categorization of objects present in natural scenes like animal vs. non-animals and vehicle vs. non-vehicles (Li et al., 2002). Given that less attention is available for the secondary task, it is expected that performance will decrease irrespective of the secondary task. The fact that supposedly complex categorizations like animals or vehicles can be performed quickly has been taken to indicate that categorization involving meaningful stimuli can occur with almost no attention. This has led to the argument that attention is not necessary for consciousness. It is to be noted that performance difference alone under conditions of less attention can be used to argue that it is not necessary for consciousness. In fact, studies have shown that performance in certain tasks can actually be better under conditions of less attention (Yeshurun and Carrasco, 1998).

Experiments on decision making have also been used to investigate the role of top-down attention (Dijksterhuis et al., 2006). In two experiments, participants chose (experiment 1) and rated (experiment 2) the best car among 4 cars in which the cars were characterized by either 4 or 12 negative or positive attributes. One had 75% positive attributes, two others had 50% positive attributes, and the remaining car had 25% positive

attributes. Each attribute was presented for 8 s. The participants were asked to make a decision either after 4 min of thinking about the cars or after 4 min of a distractor task in which they had to solve an anagram. When the number of attributes were small, performance was better when participants consciously as well as voluntarily (with top-down attention) thought about the cars compared to when they performed the distractor task. However, when the number of attributes increased (beyond the working memory capacity) to 12, the performance (choosing the right car) was better with the distractor task compared to when they thought about the cars. The study indicates that thinking without deliberate attention results in better decisions. These results have been used to argue that not only attention and awareness are different but also can oppose each other (Koch and Tsuchiya, 2007). The with-deliberate attention and without-deliberate attention conditions showing performance differences can be linked to the implicit vs. explicit dichotomy explored in the implicit learning literature (Dienes, this volume; Reber, 1980).

A particular problem with the results that show that attention may not be necessarily related to consciousness pertains to the nature of the attentional processes that may be involved in these studies. It is not clear whether the top-down attention involved in these studies is the same since these studies employ different stimuli, tasks, and actions. Top-down attention can refer to any set of processes in which the participant voluntarily chooses to do a particular behavior.

A particular way to characterize top-down attention would be in terms of two types of top-down attention, focused attention and diffuse attention. These need not be two different types but can also be two ends of a continuum in which the focus varies. Under certain conditions, diffuse attention enables processing of certain attributes than focused attention. Diffused attention will be better at larger spatial scales than smaller spatial scales. One of the factors that need to be taken into account is that participants are well aware that they need to report the gist or report the second letter in an experiment on attentional blink. When stimuli are expected, it is quite possible that top-down attention acts through instructions to form a set and performance in these tasks cannot be thought as independent of top-down attention. Hence, the findings that indicate better performance for target T2 in an attentional blink study with the dual task or positive affect conditions (Olivers and Nieuwenhuis, 2005) can be better explained by a differential attentional strategy (focused or diffused). In addition, it is also not clear why a positive affect picture should be associated with near lack of top-down attention (Olivers and Nieuwenhuis, 2005). A better explanation would be say that another dual task or positive affect pictures make attention more diffused. Positive affect has been found to modulate selective attention (Fenske and Eastwood, 2003; Dreisbach and Goschke, 2004) producing increased cognitive flexibility and a diffused mental state. Thus positive affective valence may contribute to ameliorating the attentional blink thus increasing detection performance. Under conditions when a large number of items need to be considered or are competing for attention, diffused attention may work better than focused attention. What distinguishes this claim from Koch and Tsuchiya (2007) is that while they claim that these imply lack of top-down attention, we claim that only focused attention is reduced. It is to be noted that participants are still attending to both the tasks (dual task as well as target detection in attentional blink) and attentional blink is not completely removed. Only a 10% increase in performance is obtained.

In the decision making study (Dijksterhuis et al., 2006), both consciousness and top-down attention was present during deliberation. It is not clear whether thoughts about the car were intermittently present during the distractor task. Similar to the dual task/AB study, rather than interpreting that there was no top-down attention, a better interpretation would be that more diffused attention condition resulted in better performance when the number of attributes exceeded the capacity of working memory. Similarly when the number of attributes was within working memory capacity, focused top-down attention resulted in better performance. In fact, this interpretation actually suggests that using diffused attention can be a

better strategy when capacity limitations are exceeded. Diffused attention may underlie creative solutions for difficult problems where deliberate thinking using focused top-down attention may not provide a solution (Dietrich, 2004).

In addition to different types of top-down attention, the relationship between attention and consciousness can be examined by focusing on different types of awareness. For example, two types of awareness are proposed; perceptual awareness of stimuli without attention and access awareness of stimuli (needed for reporting) with attention (Block, 2005). Another proposal for two types of awareness in which attention play a different role is by Iwasaki (1993) who proposed two different types: object consciousness and background consciousness. Object consciousness is associated with spatial attention. Background consciousness is associated with global scene analysis and possibly can be linked to "fringe consciousness" (Mangan, 1993; Norman, 2002). So, it is also possible to associate two types of consciousness, one with focused attention and another with diffused attention or no top-down attention. In this view consciousness is still closely tied to attention and attention may be necessary for consciousness. The evidence for arguing that attention is not necessary for consciousness and may even oppose is not strong. Future studies may show consciousness with the complete lack of attention but even then the relationship between attention and consciousness needs to be framed considering the different types of attention and consciousness.

It is also important to understand the role of instructions in studies involving top-down attention and consciousness. For example, in a divided attention task, the participant knows which stimuli are to be expected (through instructions), can employ top-down attentional processes (through the formation of an attentional set). More meaningful stimuli will have a higher priority and hence top-down processes through the use of voluntary attention may benefit the processing of such stimuli. One pertinent issue that has rarely been discussed is the role of attention and awareness in actions. So far, the research on elucidating the relationship between attention and consciousness has focused on primarily visual stimuli and reportability as the evidence for awareness. Verbal report is a special case of actions performed by humans and findings on consciousness from verbal report may not generalize to those from other types of actions. This is supported by findings from Marcel (1993) in which different types of responding like manual, verbal, eye-blinks are used in a visual task. Performance differed with the type of response measure used indicating that more care is needed to disentangle the role of attention and consciousness in performing a given task. Performance differences with different types of actions may also be due to conscious factors as well as unconscious (automatic) factors underlying visual performance and actions. Given these considerations, what does research on automatic or voluntary actions have to say about the link between attention and consciousness? Attention is deemed to play a large role in response selection and action planning. Does the possibility of conscious actions exist without the involvement of attention?

Concluding remarks

Is attention and consciousness the same? The preceding discussion shows that the question may not have a simple answer. Given the fact that the term "attention" may refer to multiple processes, the interesting question would be explore the relationship between different attentional processes and consciousness-related processes. It is quite plausible that some attentional processes may be tightly linked to consciousness and may be necessary for consciousness and others are not at all related to consciousness. Further research in cognitive science will throw light on the relationship between these two critical concepts that are important in understanding the mind.

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