Chapter 2
The Many Shades of Attention

2.1 Movement of Attention

It is probably not any more an interesting idea to ask the question, what is attention? William James emphasized the fact that all of us have some intuitive notion about this baffling phenomenon but none can define it. This is because attention does so many things and it is not a single process that can easily be tracked down. As indicated in Chap. 1, attention has been conceived as a binding glue which aids in object perception (Treisman and Gelade 1980), as a biasing mechanism which helps in selection of the task-relevant target (Desimone and Duncan 1995), as related to the action system (Norman and Shallice 1986), as a contributing agent in consciousness (De Brigard and Prinz 2010), etc. The attention system in the brain has been viewed as a network comprising several distinct functions such as alerting, orienting and executive control (Fan et al. 2005). Deployment of attention has also been viewed as goal directed or stimulus driven (Corbetta and Shulman 2002). This distinction refers to top-down guidance of attention specific to cognitive goals of the agent, or bottom-up capture of attention by external stimuli. This basic distinction of attentional control has been examined using the endogenous and exogenous cuing paradigm (Theeuwes 1991). This different conceptualization of attention relates to how attention has been implicated in different tasks and cognitive processes. Another crucial aspect of attention is its causal links with consciousness and its ability to bind diverse perceptions together (Cohen et al. 2012). Today, theories from object recognition to consciousness and social cognition, all use attention as a mechanism to explain a wide range of data. There is hardly any cognitive process which has not been shown to be influenced by some attentional manipulation.

One of the most striking discoveries about attention is that it can orient in space, without the movement of the eyes. Posner (1980) first demonstrated that attention can be summoned to a location using a peripheral cue. Similarly, one can direct

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attention towards a location or an object voluntarily, generally following a symbolic arrow cue. These peripheral cues were called exogenous cues and the central arrows, endogenous. The cuing paradigms have revealed that humans can deploy attention wilfully towards certain aspects of the stimuli to achieve immediate goals and this is called endogenous attention. Mostly, things in the world capture our attention and we orient towards them involuntarily, called exogenous capture. Posner made these distinctions using simple cuing tasks and these have remained influential in thinking about attention (Posner and Peterson 1990; Posner 1980). Posner thought in terms of the covert and overt movements of attention in space.

Posner used a simple detection paradigm where one has to detect a target appearing in one of the two place holders that are equidistant from a central fixation cross (Fig. 2.1). On some trials, one of the boxes is flashed briefly and this summons attention towards it reflexively. In some other trials, a central arrowhead directs attention "voluntarily" towards one of the boxes. One critical issue in this paradigm is the percentage of trials where either the brief brightening of one of the boxes or the arrow head predicts the appearance of the target. A typical finding is that, when a target appears in one of the boxes where attention had already "moved", target detection is faster. This classic paradigm is now regularly used to study covert and overt shifts of attention as well as executive control.

There are three distinct stages in such movements of attention. First, there is an orienting phase. In this phase, attention can move towards a location without eye movements. Then, depending on the perceiver's goal, attention can be engaged at that location or disengaged from the object concerned. This operates like a cycle in

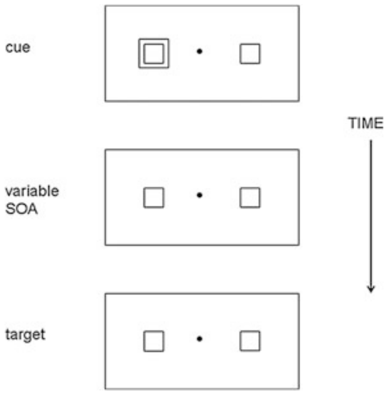

Fig. 2.1 A simple cuing paradigm showing exogenous movement of attention. One of the peripheral boxes is briefly cued. After some interval a target appears and the participant has to identify it. Target processing is facilitated when the target appears immediately at the location of the cue. However, if there is some delay, i.e. 200 m, its processing is inhibited. This is called the Inhibition of Return Effect (IOR). This figure does not show central endogenous cues. Generally, the target is a solid object which is not shown in this figure (Reproduced from Colzato et al. 2010, p. 3)

everyday situations and these distinct phases of movement of attention is linked to our overall cognitive behaviour. As agents we are constantly in need of surveying our visual environment. Klein (2000) observed that we need to constantly engage and disengage attention since we need to be constantly updating information in our visual world. Therefore, it makes sense to imagine that attention is not to be fixed at a place if nothing more is going to happen at that location.

If attention orients towards any location or object in space, because of some external sensory stimulation or even internal desire, then it is likely that objects that appear in that location later will receive priority processing. However, attentional mechanism seems to be reluctant to return to a location where it has been recently. This might be because of our novelty seeking tendency. This observation has led to a remarkable finding in the field known as the "inhibition of return" (IOR) phenomena (Posner and Cohen 1984; Klein 2000). It is a robust finding that if attention has moved towards a location and it has been disengaged from that location, then there is inhibition of further movement of attention towards the same location. However, a recent survey of attention experts of their opinions and conceptualization of "IOR" suggest that there are many different interpretations of this mechanism (Dukewich and Klein 2015). In most cases, it is seen that detecting a target object at a location where attention has moved is enhanced if this object appears immediately but detection is delayed if the target appears at a gap of, say 250–300 ms. Attention is in a constant state of motion and one can see its effect in a simple cuing paradigm with costs and benefits as function of the scope of attention (SOA) between the appearance of the cue and the target. There is, though, some controversy if both exogenous and endogenous cues give rise to IOR. It is widely believed that one may not see IOR with endogenous cues such as centrally presented arrows. Conceptually, it makes sense to imagine that with central arrow cues attention moves voluntarily and, therefore, disengagement is costly. Therefore, there might not be immediate inhibition at that location. However, IOR is commonly observed when the cues are exogenous and if attention had moved reflexively (Klein 2000). IOR indicates the constraints in the movement of attention as well as the relationship between attention and control mechanisms.

Most studies use an arrow for triggering endogenous attention shift. It is natural that arrow heads will immediately move attention in their direction since they are learnt social stimuli. Similarly, eye gazes also move attention in the direction of their gaze. By definition, endogenous attention shift should be under the control of the perceiver. However, if these social cues shift attention reflexively because of their over learnt nature; it is difficult to separate out the exogenous component from the endogenous. Hommel et al. (2001) showed that words like "left" and "right" when presented as non-predictive central cues led to attention capture. These social stimuli therefore move attention like arrows and these movements could be reflexive. Arrows and eye gaze are socially learnt symbolic cues. Therefore, the way these cues orient attention could be entirely different from pure endogenous and exogenous forms of attention (Ristic and Kingstone 2012). This way of putting it also puts attentional control into the social domains. Humans orient towards things that they know and have experienced. Automatically orienting towards the direction of an arrow or gaze indicates immediate processing of the semantics of such cues. Imagine the role arrows have on street sign boards play. This type of orienting and attentional engagements may require a very distinctive type of control different from the traditional dichotomy (Berger et al. 2005).

Interestingly, language can also move attention. Words and sentences refer to things in the world or even to internal mental states. Direction words like 'up' and 'down' shift attention reflexively and affect eye movements (Singh and Mishra 2012). Spoken words can cause visual attention to move in space towards things that they refer to and this seems to be rather automatic (Mishra et al. 2012; Salverda and Altmann 2011). The cross-modal culling of information moves attention and helps in search behaviour.

Recently, Klein and Lawrence (2011) have made an effort in grouping and classifying the various modes of attention allocation in different situations. In this framework, modes of allocation of attention is crossed with domains of attention, i.e. space, time, sense and task. This taxonomy is both intuitive and it captures a lot of experimental findings in different domains. Considering language, a performance that humans engage intentionally, it appears to be the case that both these modes of attention are utilized differently by different language activities. For example, naming a picture would require selective attention and visual object identification while listening to speech in noise may call for more filtering and control. This taxonomy reflects both the selectional and control properties of attention in different situations. The top-down and bottom-up views of attentional operations reveal something about the ways in which humans function intelligently in the world. Another way to think about the several attributes of attention is to think of it in terms of external and internal attention (Chun et al. 2011). This view acknowledges attention as comprising multiple cognitive and control mechanisms (Pashler and Sutherland 1998). Chun, Golomb, and Turk-Browne write,

> … 'external attention refers to the selection and modulation of sensory information, as it initially comes into the mind, generally in a modality-specific representation and often with episodic tags for spatial locations and points in time. This sensory information can be organized by features or into objects, which can themselves be targets of external attention. Another way to think of external attention is as perceptual attention. Internal attention refers to the selection and modulation of internally generated information, such as the contents of working memory, long-term memory, task sets, or response selection (p. 77)'.

The external aspect of attention is all about attending to things in the external world. Interestingly, one can also specifically deploy attention towards some features or aspects of objects for higher cognition and action (Wolfe and Horowitz 2004). This exogenous and endogenous distinction in the deployment of attention has proved to be crucial in how attention functions and interacts with other cognitive systems. On the other hand, internal attention can help control action. It helps in maintaining a task-specific goal for a long time and in monitoring eventualities.

2.2 Temporal Selection and Capacity Limitation

Selective attention is the key to acquisition of robust information. We move our eyes and fixate on things that we want to inspect more carefully. Selective attention on one object can block information flow from other surrounding objects. Even small insects select the targets to follow for food while ignoring others (Frye 2013). Selective attention could mean several processes like staying focused on something, ability to ignore irrelevant distractors as well as to monitor the ongoing activities for better performance.

Selective attention is necessary for processing some aspect of the stimuli while ignoring other aspects. When it comes to selection of the task-relevant stimuli from the myriad varieties that are constantly bombarding themselves on our senses, it makes sense to ask if such selection is early or late. An influential view in the psychology of attention has been that, attention basically functions as a filtering mechanism (Broadbent 1977). Attention works like a gate that controls the inflow of information for further processing. Broadbent proposed two stages of attentional filtering of incoming information. At the early stage, all stimuli undergo some filtering based on some physical measures such as pitch or location of sounds. Participants are not conscious of such early process since they happen at a very early time scale. The second stage operated in more serial manner and filtered stimuli only on the basis of some content such as meaning. This two-stage model of selective attention included the concepts of 'limited resource' and 'filtering'. The irrelevant stimuli are excluded from further processing much early in the processing cycle or do they all receive same processing for some time and then final selection follows. This dichotomy has been the most talked about theoretical issue in the modern history of attention. One way to show the functionality of the limited capacity system is to consider a filtre that allows only the most useful information for further meaningful processing (Broadbent 1958).

In this 'early' selection view, the non-attended or filtered out information will have no subsequent cognitive importance. In this conceptualization which was an 'early' selection model, the ignored stimuli were completely blocked out and no memory traces were formed (see Driver 2001 for a review). It could also be the case that all the features of ignored stimuli receive full consideration, but they are 'attenuated' (Treisman 1964). Perceivers can always separate out different messages based on their physical features, i.e. a male voice from a female voice. Often, meaning plays a crucial role in this perceptual distinction. It is not necessarily the case that the system filtres them out totally, one can still see some influence of these stimuli in later processing. Accentuation of features makes them more available to awareness and they can thus slip into memory and affect performance. Another extreme position could be that, all the signals that present themselves to the sensory processing system initially receive full processing (Deutsch and Deutsch 1963). Most of these early studies that examined filtering and selective attention in dual task situations used auditory-verbal material. The evidence that distractors can influence processing and attract attention has been considered as a support for the later selection view (Eriksen and Eriksen 1974).

Rock and Gutmann (1981) asked people to focus attention on only one colour of shapes while the visual stimuli were superimposed by other colours. A memory retrieval test showed that participants could not report the unattended features. This result suggested that the unattended features were not coded during early perceptual processing although the visual system had processed them. These results are similar to the in attentional blindness studies in the sense that unattended information escapes consciousness and subjects fail to report. However, from these results it is not possible to completely rule out that the ignored information had absolutely no effect on later processing. Later studies showed that even ignored stimuli could enter into awareness and affect response. This led to reformulation of the early models and arrival of the 'late' section models (Deutsch and Deutsch 1963). Tipper (1985) observed that participants were slower in naming a picture in a particular colour when a previously ignored distractor becomes the target in the current trial. This could only happen if the distractor had received full perceptual processing whose features are still active in influencing decision.

When is selective attention essential? One suggestion (Lavie 1995, 2000) has been that heavy perceptual or cognitive load ensures the engagement of selective attention. Load can be understood in terms of increase in the number of distractors or additional tasks. Low visual quality as well as multiple tasks demanding limited attention can also increase perceptual load. Lavie (2005) attempted to explain the distractor effect by using the 'load' metaphor. She argued that distractors may not be that influential if the main task demands sufficient amount of selective attention and taxes the cognitive system. If the task is of low load and is easy, then distractors will exert their influence. According to this theory if perceptual load is higher, there are many targets and the stimuli is degraded, then distractors may not have much influence. That is to say, if the task is attentionally demanding, people can ignore the distractors. Without a demanding task, distractors can occupy the available space and thus affect response. Lavie et al. (2004) further observed that where as a high perceptual load reduced distractor interference, high cognitive load (under a dual task) increased distractor interference, thus suggesting two modes of selective attention mechanism. Contradictory to the claims of the perceptual load theory, Roper and Vecera (2013) found flanker effects even under high perceptual load. Likewise, Yeshurun and Marciano (2013) found flanker effects even when the stimuli were perceptually degraded. These results suggest that the central claims of the load theory are still to be thoroughly evaluated and may not be as readily observable in all situations. Task demands, level of stimuli degradation, type of perceptual or cognitive load can influence target processing.

Attentional capacity at any given point in time is limited. The limited capacity of the attentional system is evident in a phenomenon called attentional blink. This arises when two different visual targets appear very close to one another temporally.

In this situation, detection of the second target is delayed (Raymond et al. 1992). Attentional blink is higher when the time lag between the first and the second target is very small, i.e. 100 m. However, with the increase in this duration, responses towards second target improve. The attentional dwell time hypothesis claims that resources are unavailable for both the targets when the first target is getting processed, particularly when the second target is presented very shortly (Ward et al. 1996). In laboratories, it is generally tested by presenting letters or numbers constantly at the same location. The participants normally detect the identity of one letter whose colour makes it distinguishable. Interestingly, when another letter quickly follows this target, often participants have difficulty in recalling the second letter. Among the many explanations of attentional blink, it seems likely that it could be a result of capacity limitation of attention. It is interesting to note that when the second target is highly salient, such as a capital letter among small letters there is no attentional blink (Shapiro et al. 1997). When attention is deployed at one location or on an object, it is likely that other events are not registered. Others have viewed this phenomenon arising from a lack of cognitive control and change in attention set. Attention set comprises the objects or entities that one wishes to temporally hold in working memory for some goal-driven action. In psychological experiments, task instructions influence attention set. For example, if the stimuli are all numbers or all words of a certain type then this constitutes an attention set.

Di Lollo et al. (2005) did not notice attentional blink when the items belonged to the same semantic category, i.e. all numbers used in the trial. However, attentional blink appeared when targets were from different semantic field. This account of attentional blink emphasizes on the maintenance of a certain attentional set for task. Di Lollo et al. proposed that there is an input filtre working at the commands of a central controlled that passes the first target based on a criteria, i.e. word or letter. If the second target is similar to the first with regard to these features, then it is easily processed. Since the input filtre does not have to change its settings for it one does not observe attentional blink for this situation when both the targets are from the same category. If the second target is from another category, then the input filtre's criteria have to be modified and this can cause processing delay. Therefore, attention blink will be observed when the two stimuli are from different categories. This evidence suggests that similarities and differences among stimuli can affect efficiency of processing as well as memory retrieval. The relevance of the task and its complexity could guide how evenly one divides the available attention resources (Kahneman 1973). Similarities and differences between the tasks could also affect performance (Allport et al. 1972). If tasks belong to the same modality, division of attention could be problematic. Limited capacity arises because of certain very core cognitive constraints. For example, one can store only four items in the visual short-term memory for some time (Luck and Vogel 1997). Things kept in working memory can only remain for a short amount of time before they vanish (Baddeley 2003). Even if we accept a limited capacity model of cognition, it is important to know how the correct stimuli are selected.

How any stimuli become our goal and how our attentional mechanisms select them for processing remain a mystery. A bright red Ferrari captures your attention while you are window-shopping. This kind of attention capture by an exogenous cue could be the result of salience of the object—its distinctiveness from its surrounding (Olivers and Humphreys 2003). However, attention captured by an exogenous cue can also be disengaged with the use of cognitive control. Mishra et al. (2012) demonstrated that highly fluent bilinguals could disengage attention capture faster in a cueing paradigm. However, distractors can catch attention and it might be difficult to pursue targets (Yantis 1993; Theeuwes et al. 1999). Maintenance of an attentional set helps target selection quickly and disengages attention from the irrelevant stuff. In any case, selective attention plays a crucial role in many such events of control. Attention during visual search can be directed to objects based on their distinctive visual features. This mode of feature-based attentional allocation is different from spatial attention. For example, searching for a particular friend in the crowd is possible as specific features of this person's face can lead to attentional bias in the visual field (Zhou and Desimone 2011). Importantly, this feature-based bias is seen when eye movements are planned to some other location (Bichot et al. 2005). It has been found that feature-based attention leads to inhibition of distractors within 100 m of target onset (Moher et al. 2014). The biased competition account of attention is an influential account which treats attention as emergent phenomena of neural mechanism and not as an agent (Duncan 1996). The theory predicts competition among visual stimuli for neural representation. In this model, multiple stimuli compete for selection at any given time and finally attention is deployed on one. This can happen through both top-down and bottom-up influences (Beck and Kastner 2009). Any pre-activated object feature can boost representation of that object and bias attention in a top-down manner. Similarly, various low-level visual features and visual organization can lead to bottom-up bias. This account does not assume a filtering model of attention; neither does it consider attention as an agent. Competition is central to its mechanisms. A lot of data from single cell recording show competition and bias leading to selection. Directing attention towards any one object leads to suppression of activity in nearby elements (Kastner et al. 1998). This bias and simultaneous suppression is affected by both top-down and bottom-up mechanisms. Desimone and Duncan (1995) influential theory of 'biased competition account'suggests that attention moves towards the targets as a function of competition between targets and distractors. When distractors are more salient, then they capture and hold attention. Even though distractors compete with targets, attention gradually gets biased towards targets.

Thus, selection through competition as a mechanism through the interplay of top-down and bottom-up factors have been considered as a central mechanism for object selection during visual search. The central question is, how, given a set of targets and distractors, selective attention is directed towards targets. Building on the basic premises of the biased competition account of target selection, an integrationist account of visual selection and action has been offered by Bundesen (1990).

According to this theory, attention allocation during visual processing is a competitive allocation of resources between targets and distractors. Given a template that consists of targets and distractors, computation of attentional weights for different category of objects take place. Attentional weights are assigned based on prior consideration of features, i.e. green objects. Importantly, in this model, only a certain number of objects can be maintained in the visual short-term memory since it has very limited space. This model also does not make a distinction between attention allocated and task-relevant or task-irrelevant stimuli initially, except the weights that are attached to them. Unlike the load theory, which emphasizes the perceptual load, the theory of visual attention (TVA) does not account for the distribution of attention to targets and distractors in terms of load or task difficulty. Thus, the load theory predicts that when there is high perceptual load, number of distractors will have no effect on processing. On the other hand, TVA proposes that the number of distractors will have an effect on target processing irrespective of perceptual load, since it considers visual working memory limitations as a major factor in selection (see Giesbrecht et al. 2014).

It is not enough to suggest that top-down goals and bottom-up factors decide what gets selected: the question is, how this mechanism works for different situations. The situation becomes complex when there are multiple targets competing with multiple distractors. Figural similarities can further complicate the matter. Bundesen (1990) proposes that attentional selection happens through two different mechanisms of 'filtering' and 'pigeon holing'. Filtering helps recognize the object and the latter processes its features. That is how initially attention is biased towards a certain object with a certain feature. When such a filtering has happened, objects that fulfil these criteria are immediately encoded into the visual short-term memory. Since the capacity of the visual short-term memory is limited (Luck and Vogel 1997), competition for selection could be stiff. While it is still not clear if distractors receive full processing before they are discarded as undesirable, it is clear that even identification of the simplest of features requires focused attention of some sort (Luck and Ford 1998). Selective attention modulates processing of items that are important.

2.3 One or Many Focuses?

The classical view on selective attention is that it has a single focus. However, if it is shown that people can attend to many objects at the same time, then one has to accept the view that attention can be deployed to several objects at the same time. Most studies with the visual search paradigm ask participants to find out only one target among some competitors. In this situation, the test participant has to keep features of this lone target in mind and search. However, on many occasions we search for many things or keep their identities in mind, although the number of

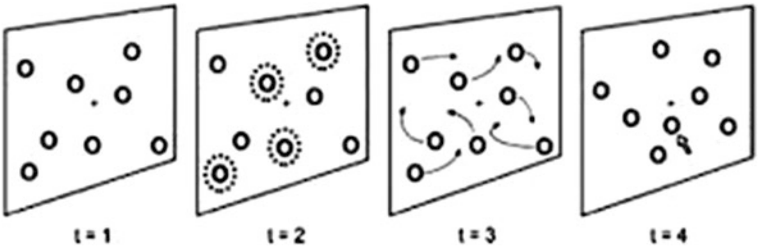

Fig. 2.2 The figure shows a multiple object tracking experiment. First a display of 8 identical objects is shown (t = 1). Then a subset of 4 'targets' are briefly flashed to make them distinctive (t = 2). Following this the objects stop flashing so the 'target' set becomes indistinguishable from the other objects. All objects then move in a random fashion for about 10 s (t = 3). Then the motion stops (t = 4) and the observer's task is to indicate all the tracked objects by clicking on each one using a computer mouse (Reproduced from Scholarpedia, 2(10): 3326)

items we can keep in our visual working memory seems limited to four (Luck and Vogel 1997). It looks like most can comfortably track a few objects and the changes they go through for some time (Pylyshyn 2003). This is like attending to any two or three children and tracking them as they are playing in a park where there are other children around. There could be a large amount of visual similarities among the target and distractor children and the number of distractor children could affect the tracking efficiency.

In the multiple objects tracking experimental set-up (Fig. 2.2), some objects are first indicated as targets and then the targets and distractors move about in the visual field for some time. The task of the participant is to say after some time if a particular item was the target. Therefore, the important measure is if one is able to simultaneously follow several targets over time. Participants actually can follow about four or five objects and do very well on the test. This can only happen if one assumes multiple focusing attributes for attention. Or, one assumes that several targets that share colour or move in the same direction with same velocity are treated as a single object (Kahneman et al. 1992). Once attention glues these various targets and treats them as one object, then tracking them can become easy. It is like tracking a flock of birds as they fly in some arrangement and cross the path of another flock. However, the question is when attention is on the flock as an object, could it still be deployed on each bird that makes the flock? The issue has consequences for some major theorization about the capacity limitation of selective idea of attention. Pylyshyn has proposed (Pylyshyn and Storm 1988) this mechanism in terms of FINST (Fingers of INSTantiations). This means, some indexes are attached to each target which then dynamically move with it. Indexes allow attention to keep track of targets.

In any case, it is likely that the available resource will be shared by all the targets. When the targets are pre-attentively indexed and tracked, later processing shows facilitation (Sears and Pylyshyn 2000). Participants are generally better in judging any change if the object undergoing change was tagged as a target. Interestingly, number of non-targets seems not to affect this process. In most multiple object tracking experiments, objects move around or change their form. In traditional visual search experiments, the display is static and changes very little. The deployment of visual short-term memory and attention is different for both cases. Similarly, the space between objects seems to be critical in tracking experiments as this has an influence on what are treated as an object (Franconeri et al. 2010a). This evidence indicates that humans can focus attention on multiple objects and carry out tasks. In the multiple object tracking studies, the important issue is related to the identity of the targets, which apparently remains constant over the tracking time. That is subjects track the same targets based on their initial identities. Franconeri et al. (2010b) observed that when targets come too close to one another, i.e. spatial distance between them is less, and then subjects have difficulty in reporting them individually. In multiple object tracking studies, subjects individuate each target and track them. However, does this mean that they keep in memory all the features of the targets that they track? Bahrami (2003) showed that even if subjects have been tracking some targets successfully they fail to notice featural changes in targets during the tracking. This means, targets are tracked with their original identity and this remains so. Bahrami (2003) also observed that subjects are better at probe detection on targets than non-targets.

The multiple object tracking studies have challenged the belief that attention has a single focus as well as the capacity limitation. The studies described above demonstrate that subjects can track around four objects over time accurately. However, it is still not clear if attention operates serially or indeed has multiple focuses (Cavanagh and Alvarej 2005 for a review).

2.4 Attention and Consciousness

Attention is needed not only for working out on current plans and goals and execute them, it also enriches our conscious awareness of such objects (Cohen et al. 2012; see also Koch and Tsuchiya 2012). One can be phenomenally conscious of certain things but needs attention to have specific knowledge about them (Block 2011). The rich environment around can influence us in many ways and we seem to have some idea about things in general but we need to focus attention on them to develop explicit and objective knowledge about them (Block 2005). Attention and consciousness are related although they could be different processes (Lamme 2004). Subjects can be conscious of certain objects without paying any attention (Koch and Tsuchiya 2007). Several researchers have tried to examine if focused attention is necessary for conscious perception. Or conscious awareness of objects can arise in the near absence of attention. One important paradigm to study these mechanisms has been priming. Bussche et al. (2010) presented primes that were either subliminal or were clearly visible. They also manipulated attention by asking participants to focus on the primes or not. The results showed that prime visibility and top-down attention had a significant influence on target recognition. This suggests that attention elevates conscious perception. These views suggest that selective attention is required only for in-depth processing of some stimuli but not always. Objects that are attended to receive rich representation in memory and are also retrieved faster (Buckner et al. 1999). Attending to something also enhances the salience of objects and makes them more prominent. When attention illuminates objects, we can act on them in a goal-oriented manner. Attention is necessary for conscious recollection of events from memory (De Brigard 2012).

One may have the illusion that one has sufficient knowledge about things in our visual world, but it is not true. At best this could be very vague, a snapshot only. To generate objective ideas about things, selective attention must be deployed. Often, it is difficult to detect changes in the environment, if selective attention is not paid (Rensink et al. 1997). Attention foregrounds objects that we are interested in and pushes others into the background. Selection of action on particular objects of choice happens through these constant shifts of attention from one to the other. This gives us a sense of control on our action and our goal directedness (e.g. Frith 2002). Many a times, we just look at some objects since they capture our attention for reasons beyond our control. It has also been argued that without the deployment of attention, objects escape our consciousness awareness (Simons 2000; Wu 2011). Termed as in attentional blindness, this phenomenon means that without paying attention one cannot perceive an object (Mack 2003). People fail to detect changes or another event occurring in the visual field, if they are attending selectively to some specific object or event (Simons 2000). Drew et al. (2013) asked expert radiologists, who have spent years examining images and apparently have the ability to detect small changes in them, to detect a gorilla in some of the pictures. The gorilla was too large to be missed. Interestingly, 83 % of the radiologists could not see the gorilla; however, their eye movement record showed that they had fixated on the gorilla.

This evidence suggests that without selective attention even a very large and salient visual event can escape our consciousness. Furthermore, participants can sometimes report events and objects if they are primed and if a suitable context is provided. Slavich and Zimbardo (2013) observed that a majority of participants could not locate the figure of a suicidal woman in a picture that was suspended mid-air even though they saw the picture many times. However, when primed with a story related to suicide, some of them could locate the woman. This suggests that past experience and context can direct attention towards relevant locations in the visual field and thus enable us to locate objects. Listeners cannot detect changes even in their native language when their attention is not cued (Neuohff et al. 2014). All this evidence suggests a close link between selective attention, conscious perception and our ability to observe.

2.5 Visual Search

How do we search for things in the real world? Sometimes the search for targets is easy since the target could be sufficiently salient from its environment. It is very easy to find out the X in Fig. 2.3a since it pops up. This does not call for deployment of selective attention and search may progress in parallel (Treisman and Gelade 1980). This kind of search is purely bottom-up. In contrast to this, searching the inverted T in Fig. 2.3b is difficult and may involve serial search. This involves blending of two features, i.e. identity and its orientation. When the set size, i.e. number of other items that are not targets increase, search times also increase differently for these two types of searches. What is also crucial to note here is the feature similarities between targets and distractors. The more similar the distractors are to the targets, the more features they share and the search requires higher focused attention. Attention also works as a glue for different types of perception and leads to some holistic gestalt (Treisman and Gelade 1980). If one is looking for a red cube whose boundaries are also solid, then, it is necessary to keep these two features glued for efficient search. This is what probably Wittgenstein had in mind

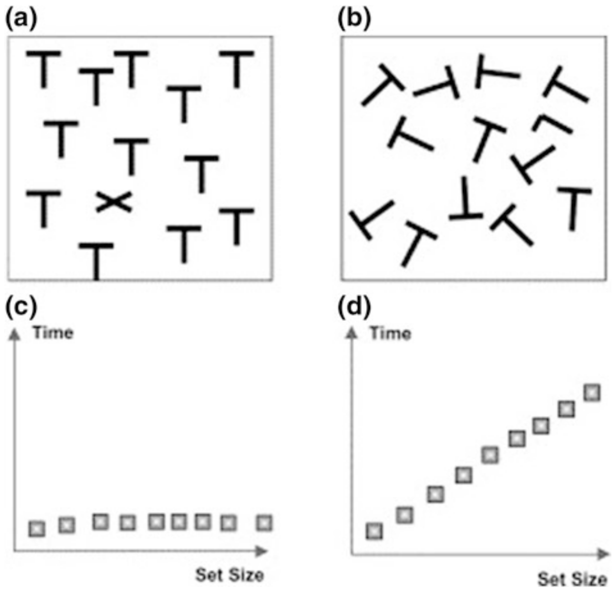

Fig. 2.3 The *top left panel* shows a simple visual search where the target 'pops out'. The *top right* shows a sample of what is known as a 'conjoined' search. Here finding the target, L involves keeping the letter identity as well its orientation in mind and this search requires serial application of selective attention. The bottom results show increase in target detection speed for these two types of searches. Set size refers to the total number of items on the search display. While the increase in set size affects the efficiency of conjoined search, it does not affect much the simple search (Reproduced from Yang et al. 2002, p. 293)

when he said that a child needs to pay attention to both the spoken form and the visual object in order to grasp the essence of the object (Wittgenstein 2010). Two different types of signs thus could be unified and represent an object. Different features of visual objects are tied together with the involvement of attention (Wolfe 2012; see also Di Lollo 2012).

Top-down and bottom-up attention control mechanisms have been found to engage different brain networks. In a study with young children and older adults, Li et al. (2013) observed that older adults recruited more frontal and parietal regions for both serial and parallel search tasks. Children recruited more parietal areas for the pop-out search whereas adults recruited the parietal and frontal areas more equally. This evidence suggests that cognitive control mechanisms interact with these two types of searches. Buschman and Miller (2007) observed frontal neurons signalling top-down attention control early on in search task and partial neurons for bottom-up task in primates. This indicates neural specialization for these two types of attention allocation. Top-down attention takes time to act while bottom-up attention is immediately activated.

An important question in this debate between top-down and bottom-up attention control has been if salient stimuli capture attention unintentionally. If that is so, this could demonstrate the fallibility of top-down attention control. This debate has also been around the issue of the time scale at which top-down and bottom-up attention exert their influence. Human agents deploy attention towards task-relevant stimuli wilfully. This has been hailed as top-down control of attention. On the other hand, attention is also captured unintentionally by several objects in the environment. This has been variously called as bottom-up capture of attention. The earlier example of parallel search where the salient target captured attention can be considered an example of bottom-up capture. However, this can also be considered top-down since the participants knew 'what' object they were searching for Kim and Cave (1999) asked observers to search for a unique target while the display had a salient coloured distractor. Data showed that this distractor captured attention early on but attention returned to the target later. This suggested that top-down factors did not prevent attention capture by distractor. However, Lamy et al. (2003) found that when a conjoined search task is given, i.e. search cannot be accomplished with the pop-out mode, then the salient distractors did not capture attention. This suggested that top-down attention can act early on and prevent attention capture. However, it is not clear from these studies if the type of search, i.e. serial vs. Parallel is the key to contingent capture. There is evidence which suggests any salient stimuli will capture attention irrespective of the relationship it has with the target (Theeuwes 1992). In contrast to this, 'contingent capture' theorists suggest that a singleton will capture attention if it matches in features with the target (Folk and Remington 1998). Theeuwes (1992) asked observers to respond to the orientation of line inside a target diamond surrounded by other distractor circles. On some trials one of the distractor circles was in green colour. This led to attention capture and delay in judgement. This happened when the colour of the circle had no similarity with the diamond's colour. Thus suggesting that such a pure capture of attention is involuntary and operates in a bottom-up manner very early during visual processing. This depends on the salience of the distractor and is pre-attentive. Folk and Remington (1998), however, observed that if distractors and targets match in colour or in some feature, then there is attention capture. When distractors were in green and targets were in red, then there is no capture of attention by the distractor. This suggests that early on attention exerts top-down influence on visual processing.

Another group of studies have shown that contents of working memory can guide attention automatically and any item matching to the working memory contents can lead to attention capture. However, there are conflicting facts around these phenomena. Olivers et al. (2006) found that singletons capture attention more strongly when they matched items held in working memory. Further, these singletons attracted eye movements but fixation durations were not affected. This suggested that participants could disengage attention from contingent capture soon. In another study, Soto et al. (2005) asked participants to identify a tilted line among vertical distractors. This line was within a shape with a unique colour. Importantly, on some trials this shape matched an item held in working memory. Search was efficient when there was a match between the shape and working memory shape. However, on a similar visual search design, Woodman and Luck (2007) did not find any attention capture by distractors that matched working memory contents. Rather, they observed that participants could avoid looking at the distractors, suggesting a flexible manipulation of working memory contents for action. Han and Kim (2009) made the search difficult by manipulating the perceptual salience and also delayed the search onset. They found that in such cases there is no automatic guidance of attention from working memory. The authors suggested that a perceptually difficult search can eliminate the automatic capture and delay caused cognitive control to operate top-down effects on search. Therefore, while the issue of automatic guidance remains controversial it is important to understand that attention capture can happen through many means and working memory plays a key role. An item matching in features with the target can capture attention and this is called contingent capture distractors (Wyble et al. 2013). Visuo-spatial attention works as a filtering agent exerting top-down influence on attention capture (Theeuwes et al. 2010). An object's visual distinctiveness makes it a good candidate for attention selection (Itti et al. 1998; Serences and Yantis 2006). Cognitive agents bias their attention towards task-relevant objects or locations and avoid distractors using top-down experiential knowledge (Gazzaley and Nobre 2012).

2.6 Scope of Attention

So far we have seen that attention has been viewed as a limited capacity filtering agent as well as a component in cognitive control. We also saw the manner in which attention can be deployed during visual search, i.e. top-down and bottom-up. Another important property of visuo-spatial attention is its aperture. Attention has always been imagined like a light beam which illuminates aspects of the world for the cognitive system to process. It appears that one can wilfully 'broaden' or 'narrow' down the spatial scope of attention during visual perception. For example, while looking at the scene of a forest, one can look at the entire forest, the clusters of trees and other things without specifically paying attention to any particular object. This broad view helps in perceiving the whole object; provides a kind of holistic vision. Similarly, one can be asked to count the number of leaves on a plant and so on. To do so, the subject has to specifically focus on each leaf. One can deploy attention on a 'global' scale as well as to 'local' elements.

Global attention is diffused and is generally spread across multiple objects. These attentional states are induced by asking participants to process these hierarchical figures in one or another mode. And also in other situations, participants can themselves deploy these modes in a top-down manner. An analogous event in the domain of language will be to ask someone to just focus on the overall meaning of a sentence or its specific parts. It can be then assumed that in the former case, a kind of global attentional mode operates while in the latter case a local mode is relevant.

A long running idea in this domain has been that visual perception operates at a global level by default. That is we see the forest first and then the trees. Navon proposed the 'global precedence' hypothesis to suggest that the visual perception system processes global features more immediately and with some primacy. Navon did early experiments on this idea (1977) with hierarchical figures. Hierarchical figures are made out of simple figures (Fig. 2.4). For example a large five made out of small fives [congruent] or made out of small sixes [incongruent]. One is asked to count the number of letters that compose the large letter and it is assumed that in doing so one is using the 'narrow' focus of attention. If asked about just the identity of the large number then global attention can be sufficient. Navon (1977) found that

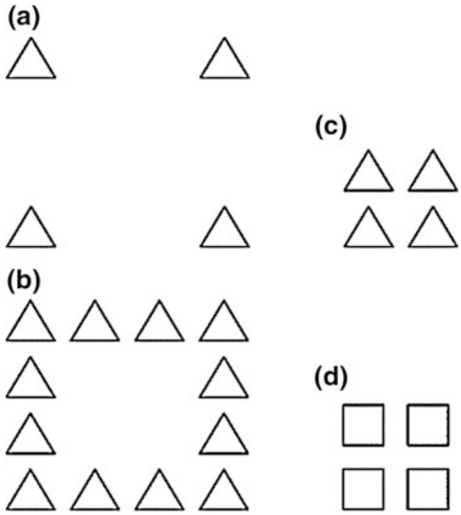

Fig. 2.4 Different representations of global and local levels. A square made out of small triangles could be problematic to perceive as compared to a square made out of squares. This compatibility between global and local levels has been important for object recognition. *Source* Navon (2003, p. 276)

participants had interference in naming an auditorily presented letter while focusing on the global level of a hierarchical figure. Subjects also suffered interference when the global level of a hierarchical figure was incongruent with the local level. This suggested that attention operates at a global level in the beginning and then at a local level. Navon (1981) observed that with exposure duration of 150 m, participants were good at identifying the global letters and were also good at discriminating a tone but were slow with the local letters. Navon, argued that the global processing is a default processing mode and precedes the local processing mode. The global processing mode thus employed the broad scope of attention while the local level called for more focused and effortful attention. De Cesarei and Loftus (2011) presented high and low passed filtered images of objects, faces and hybrid images to participants for identification. A global presence was found thus confirming that the theory generalizes to all types of stimuli and even to perceptually degraded stimuli.

Brain imaging studies have shown that selection of visual scenes for either 'global' or 'local' type of processing happens in distinct cortical sites. The right lingual gyrus is activated when one is deploying 'global' attention to a scene, i.e. looking at the forest, while the left inferior occipital cortex gets activated when one is in a state of 'local' attention, i.e. counting the trees (Fink et al. 1996). If one is asked to first process a scene under a 'global' mode and then some other stimuli is presented which also demands a 'global' mode of processing then there is facilitation (Ward 1982). There is conflict when the two modes of attention are different. Switching between global and local attention states influences psychological processing. Mishra and Singh (2012) presented hierarchical figures and then written sentences for judgement. The hypothesis was that attending to either global or local level should affect overall reading times and judgement. There were sentences with morpho-syntactic problems as well as sentences with semantic problems and normal sentences. The result showed that participants were slower in reading as well as judging sentences of all types when they focused their attention at the global level but were faster when they focused attention at the local level. This suggested that global and local attention states can affect processing of linguistic stimuli differently. However, this study did not find any interaction with the mode of attention of type of sentences.

The zoom lens view assumes that attention can be shifted from narrow scope to broad scope voluntarily depending on the task at hand. When under diffused state of attention, one can discriminate only very broad features of objects, e.g. colour, but a focused beam is required when more details about the object is required. Selective attention is deployed during the narrow or focused state and objects or features of objects are 'foveated'. Scope of attention can be thought of as a gradient, spread out over the entire visual field (LaBerge and Brown 1989). Visual acuity falls off gradually as one moves from the centre to the periphery and this affects processing and discrimination. During focusing on a word while reading a sentence, it is possible to be vaguely aware of the words to the left or right but it is difficult to be sure of their details. This means, in order to know their details, eyes have to be moved towards them to bring them under foveal processing (Rayner 1998). Movement of the eyes is essential to bring newer objects under the fovea and deploy selective attention. Therefore, the gradient view of attentional shifts views movement of attention as a dynamic thing. Thus, the studies with hierarchical figures show that attention has different levels of scope and these levels affect perceptual processing.

2.7 Attention, Control and Action

Attention is first and foremost linked to our limited capacity to process information. Michel Posner notes that attention should not just be viewed as a selection mechanism but a way of the mind to act in the world (Posner 2012). The brain has to select the most relevant information for processing among competing stimuli for optimal cognitive processing. Amid the constant flux of myriad sensory events, one needs to find goal-specific information, select objects and 21hannelizi action (Neumann et al. 1986). If this were not the case, then we would not be in control of our thoughts and action. Nevertheless in spite of our top-down control, attention is often captured by peripheral cues that may not be task relevant (Johnston et al. 1990). Selection and goal-directed actions have been conceived as crucial attributes of attention (Posner 2011; Cohen 2014). Selection of the goal-relevant stimuli is affected by many other competing stimuli in the environment. Therefore, the need to select the most relevant stimuli is crucial for successful cognition and survival. Our cognitive limitations do not allow for simultaneously coordinating many actions. Thus attention helps filtre and focus on the task-relevant phenomena.

One can select, focus and act wilfully because of attention. It is the view that attention is useful for action, and that goal-directed action is important for the understanding of language–attention interaction. That is because language is also an action-based system (Pulvermuller 1995), though symbolic. Broca's area has been found to be active not only during language processing but also in action observation, suggesting a high degree of overlap between the linguistic and action systems (Willems et al. 2007). Selecting the right language itself might call for attention selection as it has been observed in bilingual language processing (Green 1998). Therefore, attention and language interaction has to be understood in terms of selection, control as well as focusing features of the attention. The control of 21hanneliz or its regulation is important for cognition. Attention affects the way our thoughts and actions synchronize (Posner 2012). Actions crucially depend on selection of the right goal, maintenance of information and sorting out conflicts timely.

Humans can control their action by resisting interference from 21hannelizin and selecting the correct response. For example, to pick an apple one has to control interference from oranges, since they resemble an apple in shape and also belong to the same semantic field. Studies have shown that unintentionally the action system gets briefly biased towards 21hannelizin in such situations (Duran et al. 2010).

Several important brain networks have been implicated that suggest the regulatory function of attention in such situations (Posner 1994). Both top-down and bottom-up factors can affect such control processes. Top-down effects may include current goals, motives as well as task instructions; whereas, bottom-up influences arise from the salient properties of the stimuli themselves. Attention plays a role in controlling distractor interference (Serences et al. 2005; Lleras et al. 2013 for a recent review on this issue). Therefore, apart from the selectional role, attention aids in cognitive control.

Current cognitive goals are required to be translated into action and 22hanneliz. Attention plays a crucial role in translating these goals into action (Monsell and Driver 2000; Posner and Fan 2007). This aspect of attention is important for linguistic processes like speaking and discourse (Brennan 1995). Often goals have to be maintained for a longer period of time so that there is no interruption in the execution of action. This maintenance of information and action schema in the working memory is taken care of by the executive control system (Miller and Cohen 2001). Attention's role as a selection mechanism is linked to this conceptualization. Second, attention's role in goal-directed 22hanneliz has often been used by language researchers for a long time (see Allport 1993).

Attention first and foremost influences control on our thoughts and action. Actions that are habitually performed appear automatic. Such tasks do not call for voluntary attention. Reading, speaking and listening look automatic to all from this perspective. The dichotomy between 'controlled' vs. 'automatic 'processing indicate differential involvement of attention (Kahneman 1973; Shiffrin and Schneider 1977). Controlled processes require attentional engagement and they are often voluntary. On the other hand, automatic processes require no attentional resources and get instantiated and complete their cycle, sometimes even unconsciously (Norman and Shallice 1980; Posner 1978) However, if there is change in the action plan or a conflict arises where the habitual response might lead to more problem or when one has to stop a wrong action plan, then cognitive control becomes necessary. Tasks that are effortful require attention.

In a comprehensive conceptualization of automaticity, Bargh (1994) separated automaticity into four components. They were awareness, intention, efficiency and control (see also Moors and De Houwer 2006). More recently, Bargh has written, 'Automaticity means the direct environmental control over internal cognitive processes involved in perception, judgment, behaviour, and goal pursuits' (Bargh 2011, p. 629). There are some processes that seem automatic in the sense that they are activated and processed without the requirement of focal attention. For example, in a priming task, the activation and later influence of the prime on target processing is automatic. This happens when the prime is perceived subliminally. In some situations, focal attention is required for identification and perception. Automatic processes could be just reflexes (Anthony and Grahme 1985). Reflexes are things that our cognitive systems have acquired by experience and spreading activation leads to their automaticity. For example, the temptation to look at the direction of an arrow is a reflex since an arrow is a socially learnt stimulus. Cognitive control is necessary to stop an action that has come about because of some reflex.

Attention, apart from being a selective and a filtering mechanism, becomes crucial in inhibition of task-irrelevant responses. Many a times one has to focus attention on one aspect of a task while ignoring other aspects. For example, in a Stroop task, attention has to be given to the colour of the word while ignoring the meaning of the task. Therefore, conflict resolution in such tasks calls for selective attention. The executive control system exercises inhibitory control to deal with such a situation (Botvinick et al. 2001). The prefrontal cortex and the anterior cingulate cortex show activity during sustained attention tasks (Miller 2000). An eventual conflict then can be easily handled with higher alertness and change in the response. Many important theories of conflict resolution have accorded a central role to attention (Botvinick et al. 2001). Task-related goals must be kept in working memory. Attending to this information held in working memory requires executive attention (Engle 2002).

2.8 Attention in Scene Perception

The studies described so far have employed well-defined laboratory-based tasks where participants gave responses to stimuli under experimental conditions. The studies with attention blink as well as with attention scope showed different facets of attention. However, one wonders how attention operates when one is viewing a real-life complex scene, i.e. a photograph. What kind of top-down and bottom-up factors influence scene viewing? The use of eye tracking has led to important discoveries about the mechanism of scene perception, attention as well as memory (Henderson 2003). The real world is full of objects and often they are embedded against one another in a rich and scattered canopy. Objects in the real world do not come organized as they are often in psychological tasks. Even features that we have to blend together for search might be very diverse. Then, what guides visual search in the real world? This issue is crucial to understand how attention interacts with language since language refers to things in the real world and influences attention. Visual semantics and scene context could guide attention during a scene search. Interestingly, objects consistent with the scene schema are identified faster and reported better (Davenport and Potter 2004). Similarly, when objects do not go well with the scene semantics, they pop out and capture attention (Hollingworth and Henderson 1998). However, this popping out is because of very early activation of conceptual knowledge that make the scene-inconsistent object salient and not so much due to its visual features. Scene semantics is rooted in our knowledge of objects and their everyday locations. The cognitive goals of the perceiver and task goals influence where people look in a scene and in what order they look (Buswell 1935). There is a close relationship between what people know in general about things and what experience they have had with such scenes (see Intraub 2012).

An important debate in this domain of research has been on the issue of attentional involvement in scene perception. Does one need focal attention for scene perception? And a second issue has been around the top-down and bottom-up factors in scene perception. Many studies that have investigated real-world search have used complex scenes, mostly photographs. It is known that within a very brief amount of time, viewers can register the gist of scenes (Fei-Fei et al. 2007). Often, the claim is that this sort of gist is acquired without attentional engagement (Fei-Fei et al. 2002). It is natural that with a brief glance there is not much time to look around and get details. The knowledge received from a gist could be very vague, e.g., the scene of a beach. You would not be able to tell the colour of the cap of the boy who was standing near the palm tree. For this to happen, you should deploy selective attention to the object concerned. Report of information is always better when some amount of attention is paid to the scene (Mack and Clark 2012). However, Cohen et al. (2011) argued that when the primary task is demanding, when participants are asked to recognize scenes under a dual task situation, then attention is necessary for perception. Therefore, whether scene perception requires attention depends on the task demands and cognitive goals of the perceiver. Even if it is possible to acquire some gist in a brief amount of time, one needs to deploy focal attention for more objective processing of scenes.

As for the issue of top-down versus bottom-up factors in scene perception, there have been two dominant views. One view has been that the cognitive goals of the perceiver guide scene perception (Henderson 2003), while others have offered a more stimuli-based account of scene perception, suggesting that eyes move around salient locations in a scene. Itti et al. (1998) showed that scene saliency attracts eye movements. It is evident that human observers do not look at things predicted by computational models that only consider the visual salience of things (Foulsham and Underwood 2008). Underwood et al. (2006) directly examined of scene saliency attracts eye movements during scene perception. They presented scenes that contained objects that were either highly salient or had low salience value. In the first task, participants had to look at the scene for a later memory task while in the second, task participants were asked to identify a low salient target in the scene. In the first task, participants looked more often at the highly salient objects while in the second task, the highly salient object failed to attract attention. The study thus demonstrated that when perceivers view scenes with a cognitive task, low-level visual factors do not dominate visual perception. Bottom-up theorists believe that low-level salience of things capture and guide attention (Wolfe 1994). However, many think it is the cognitive goal of the perceiver and context that guides attention in the real world (Henderson et al. 2007). Depending on what information one is looking for, one will look around the scene in a particular manner (Henderson 2003).

Visual context and top-down knowledge seem paramount for 25hannelizing attention during real-world scene perception. Language interacts with scene semantics and affects attention dynamically (Knoeferle and Crocker 2010). Selective visual attention to different objects in a scene is an outcome of what we know about the scene, what we are looking for and what we listen about it. It is apparent that these events are vastly complicated compared to the simple search tasks described before.

2.9 Attention, Language and Eye Movements

It is not enough to talk about attention with data from a single modality but it is also important to look at the contexts where information from multiple modalities interact and influence one another. A rich history of psychological research tells us that attentional shifts in one modality are sensitive to events in another (Driver and Spence 1998). Psycholinguists have shown that language input influences attention shifts. Eye movements are crucial indicators of such shifts in internal and external attention. For example, the spoken word 'apple' can drive eye movements towards a fruit basket. This sort of saccadic eye movement is both automatic and show sensitivity to both visual and linguistic context (see Mishra et al. 2013). Most researchers study basic eye movements like saccades, fixations and smooth pursuit as well as micro-saccades in certain specific situations. These days many different types of eye trackers are easily available to study human cognitive functions (Rayner 1998).

Eye movements over a scene and their patterns can also indicate the cognitive goals of the perceiver. It is known since the early studies of Yarbus (1967) that human participants look around a space depending on their goals. Yarbus asked participants to search for specific information in a painting and each time he found very different scan paths (sequential movement of eyes). This was interpreted suggesting that scan paths indicate the 'route' goal-directed plans take. Yarbus's simple experiment was a powerful way to examine how our top-down goals and experiences affect the way we survey the world around us—suggesting that eye movements are controlled by intentional factors and can indicate cognitive Eyestates. Eye movements, therefore, largely reflect goal-driven cognitive plans of perceivers. Measurement of eye movements in cognitive tasks can tell us about certain 'cognitive plans' of the participants even when they themselves may not be aware of these movements. Eye movements are unconscious most of the time and participants do not always remember where they were looking. Once it is established that eye movements reflect the locus of cognitive processing, it makes sense to use them in understanding how attention interacts with language processing in different contexts.

The use of eye movements as dependent measures in the exploration of many cognitive tasks like reading, speaking, listening and scene perception can reveal facts about attentional mechanisms (Rayner 2009; Mishra 2009). With sophisticated and less expensive eye trackers available, it is now easy to measure these fast movements in a variety of real-life and experimental situations and even with infants and neuropsychological patients. Eye movements to a location follow covert attention shifts to that location (Sheliga et al. 1994). Some have argued that when one shifts attention covertly and does not make an eye movement immediately, it is as good as having made a saccade. Covert attention shifts are nothing but unexecuted saccades (Rizzolatti et al. 1994). This means one can select a target for possible saccades but may not look there. Therefore, covert orienting towards a

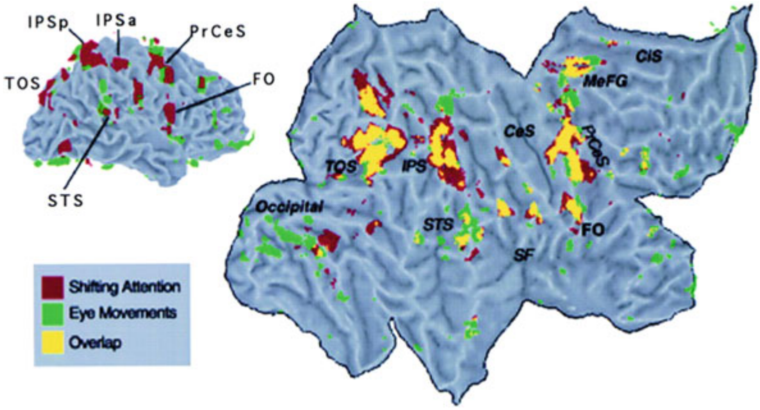

Fig. 2.5 Figure showing neural activation in the *left* and the *right* hemispheres in eye movement and attention tasks. The *red areas* indicate activation of cortical areas during attention tasks and *green* indicate areas active during eye movement tasks. The *yellow areas* indicate common areas active during both the tasks. In this study, participants shifted attention to a location with or without eye movements. Several *common areas* indicate a single common mechanism for these two cognitive systems (Reproduced from Corbetta et al. 1998, p. 834)

location or object in space is a by-product of the mechanisms of the oculomotor system. Not many though agree today with the strong version of this proposal but the idea remains quite attractive to those researchers who use eye movements in their researches to measure 'attentional' shifts. They tactically assume that looking at something means the subject is paying attention and therefore eye movements as a response system are cognitively interesting.

Eye movements and attention shifts could be independent systems, at least functionally (Klein 1980). This proposal suggests that attention shifts and eye movements arise for different reasons and thus should not be treated as the same mechanisms. However, other theorists believe that eye movements are nothing but a reflection of overt shifts of attention and one must treat them as the same system. Neuroimaging studies have observed significant overlap between the neural structures responsible for eye movements and attention shifts (Corbetta 1998; see Fig. 2.5).

An important issue here is whether prior attention shift is necessary for saccades towards an object or special location. By far, the strongest evidence that suggests a causal link between visuo-spatial attention and saccade generation comes from an experiment by Hoffman and Subramanium (1995). The researchers asked participants to programme a saccade towards a location while they were required to detect a visual target presented just before the actual eye movement. Participants were faster and more accurate in target detection when the location of the programmed saccade was the same as the location of the target. This result suggested that visuo-spatial attention and its movement are functionally related to the execution of saccades. Further experiments showed that it is practically impossible to move the eyes in one direction while shifting attention in some other direction. Similarly, Shepherd et al. (1986) attempted to separately manipulate attention shifts and eye movements. Participants were asked to programme a saccade towards a peripheral target while a centrally presented arrow indicated the location of the possible target. Centrally presented arrows have been known to cause voluntary shifts of attention in the arrow direction as well as indicating the likely appearance of the target. Participants were faster in making a correct eye movement towards a peripheral target if it appeared in the direction of the arrow. This suggested that preparing to make a saccade towards a location substantially brings down the saccadic reaction time to targets presented at that location and this indicates the effect of spatial attention shift. Saccadic reaction times could be higher if the targets appear somewhere else, indicating a cost. Therefore, this evidence might suggest that making an eye movement indicates allocation of attention and this shift of attention precedes eye movements. Deubel and Schneider (1995) examined if attention focus and saccade programming are interlinked. Deubel and Schneider (1995) observed that when participants were asked to programme a saccade towards a specific location, later target discrimination at that location improved. This could suggest that programming a saccade leads to covert attention shift to a location, even when no eye movements are made.

Attention and eye movements seem to be linked intimately and one can study them both using neurophysiological and behavioural methodologies. In an important study done with primates, Moore and Fallah (2001) stimulated the primates' frontal eye field neurons while the participants were asked to make eye movements to visually presented targets. It was observed that stimulation of these oculomotor neurons also caused shifts in spatial attention. Participants were faster in detecting the object when the object occupied a space within the receptive field of the stimulated oculomotor neuron. Further evidence for a direct role of oculomotor neurons in visual target selection has come from studies with primates where micro-stimulation of superior colliculus neurons have been shown to directly modulate saccade target selection. It has been long known that superior colliculus neurons play a critical role in saccade generation. Carello and Krauzlis (2004) trained monkeys to make saccades towards visual targets that they selected based on colour discrimination. This design was novel in the sense that this included a direct manipulation of intention given the fact that the primates selected their next saccadic target based on the colour feature. The visual targets appeared in the opposite hemi-fields. Micro-stimulation of the superior colliculus neurons resulted in faster selection of the appropriate target and a decrease in reaction time.

These data suggest that saccades necessarily indicate attentional shifts. Eye movements cannot be made without already committing attention to a location. However, attention can move without eye movements. This, of course, flows from the influential pre-motor theory that considers covert spatial attention as a by-product of an oculomotor programme. Covert orienting of spatial attention can be independently studied without the simultaneous initiation of an oculomotor response (Klein 1980; Klein and Pontefract 1994).

Recently, Belopolsky and Theewwes (2012) explored the issue further with a visual search task. It was investigated if covert shifting of attention is always followed by a saccade to that location. Participants were asked to search for numbers among letters that came at different locations on the computer screen. Moreover, participants were asked to 'covertly' search for the number and then make an eye movement towards that location. Each number, i.e. 1, 2, 3 and 4 were linked up with four locations. It was observed that covert shifts of attention were coupled with the activation of a saccadic programme but an eye movement did not always result. However, a very interesting pattern of results emerged when participants were asked to 'maintain' attention covertly at the location. There was suppression of the oculomotor programme. This evidence suggests that shifts of visuo-spatial attention, and target selection is functionally linked with those very neurons that move the eyes in space. Sometimes a random peripheral object attracts attention in a bottom-up manner and we move our eyes towards this object. In this case, the eye movement is not under the volitional control of the subject and indicates a shift of attention, leading to a saccade.

A considerable amount of research in psycholinguistics and related disciplines has been on the issue of language and its interaction with attention and vision (see Ferreira and Henderson 2004; Spivey et al. 2001). This research attempts to integrate findings and theoretical frameworks from vision, perception, attention and language. A commonly used paradigm has been to use spoken language and visual simultaneously and measure scanning behaviour. For example, with a display that contains four objects—the picture of a candle, a candy, a towel and a fish, when the word 'candle' is presented, eyes also move towards the picture of a 'candy' (Allopena et al. 1998; see also Huettig and Altmann 2005). This covert shift of attention and saccades towards an object that is not relevant for the listener indicates attention shift because of incremental processing of phonological information. These eye movements also may reflect consideration of multiple items before the target best matching to the input is selected. Objects consistent with the input attract attention. Others have found that even objects that share the same shape or even colour can attract attention and listeners look at them (Huettig and Altmann 2011). This type of eye movements during search with real-world objects indicates some type of 'unintentional' activation of the oculomotor system. This can also happen even when perceivers have been explicitly asked to search only one object and move their eyes towards it and not to other items (Salverda and Altmann 2011). Language thus mobilizes attentional shifts in the visual world. This is accomplished with the referential functions of language and a close match between linguistic input and visual concepts.

These eye movements reflect emerging attentional bias because of incremental processing of language and visual information (Mishra and Marmalejo-Ramos 2010). Spoken words have been shown to cause a great deal of interference with visual tasks (Salverda and Altmann 2011). Similarly people look at unrelated and task-irrelevant objects when their primary goal is to look at something else (see Mishra 2009 for a review). No one wants to look around apples when you want to buy oranges. It appears that objects can therefore capture attention unintentionally and once attention is captured then there is an obligatorily eye movement. Many so called ‘visual world’ eye tracking studies that present visual displays and spoken words simultaneously exploit such a situation. Interestingly, this covert shift of attention towards a related object is completely unconscious and happens for a brief amount of time (Mishra et al. 2012). This situation is also similar to where the onset of a distractor captures attention and saccades are programmed towards them. It is another matter that once the perceiver realises that the object is not the target he/she quickly corrects the saccade.

At other times, eye movements and therefore shifts in attention towards some location or objects can be unintentional and anticipatory. Eye movements reflect cognitive operations that are ongoing and not yet complete (Spivey 2008). For example, given few objects to look at, people often inspect unrelated objects briefly before making a final saccade towards the target. This transitory aspect of eye movements and looking behaviour reflects how dynamically cognitive states evolve in real time. This means, eye movements can be linked to those stages of evolution of a decision making process. Moreover, eye movements can indicate anticipatory cognitive processing in many situations. We have seen so far that in experimental psychological tasks, participants are often given very fixed instructions to attend or move their eyes to certain locations and they often do a task. Be it the cuing paradigm or even tasks that measure covert shifts of eye movements, participants operate under fixed task instructions and attention shift is then contingent on such task goals. However, this may not be always the case in some situations.

Human agents use their real-world knowledge and also structural knowledge of language to shift attention towards objects that are task relevant. In the first demonstration of ‘anticipatory’ eye movements during spoken sentence processing, Altmann and Kamide (1999) observed that listeners quickly move their attention towards objects that are compatible with the sentence context and even with the grammatical tense of the verbs used. Altmann, Kamide and Heyood (2003) used clipart scenes that depicted a boy, a man, a mug of beer and a cookie. When the sentence ‘the boy will drink/eat ‘was presented participants quickly oriented their attention and looked at the picture of the ‘cookie’ and when the sentence was ‘the man will drink’, immediately with the onset of the verb, participants looked at the beer mug. This suggests that attention shifts during real-world scene viewing is often contingent with real-world knowledge and event structures. People know already what things are and how they are related to real-life experience. Many more studies have ever since investigated these effects and there is now a great deal of consensus that attention shift can be anticipatory in many real-world situations and they can then cause shifts in eye movements. Therefore, a complete understanding of the nature of attention and how it is related to cognitive processing must go beyond viewing it just as some sort of limited resource or a filtering mechanism. It is still not clear why we look at things even when we know that they are not objects representing our immediate goals.

2.10 Conclusion

Considerable theoretical and experimental progress in attention research has shown that attention is an all-pervasive system that aids successful cognition. The chapter presented some of the most important attributes of attention. It is important to note that considerable controversies exist in each of these domains as far as results are concerned. However, some of these attributes will be crucial in understanding its interaction with language. I will end the chapter with another strong position recently echoed by Brit Anderson. Anderson says that "attention never causes anything. Because there is no such thing as attention. There are many empirical findings that can be accurately labelled attentional. In a phrase, attention is more adjectival than nominal" (Anderson 2011, p. 2). This sums up the current confusion in the field of attention as it is. Attention is a process that basically allows us to channelize our limited cognitive resources towards the most immediate issues in the environment (Carrasco 2009). Attentional processes affect the way we survey our natural world and perceive it. Attention modulates our consciousness experience. Even though there are disagreements on what attention is or what processes need it, there is also quite a bit of agreement among researchers about its essential nature. Such as, it is a limited resource; one needs it to process something more accurately and attention shifts to a location without eye movements can enhance perceptual discrimination. There is also currently much work on the relationship between attention and working memory. For example, many believe that to keep something in working memory for a later action is equivalent to 'attending' to it (Engle 2002). The demonstration that manipulating the scope of attention can lead to differential processing of other stimuli is an elegant notion that can be used fruitfully to study language–attention interaction. Psycholinguists have been currently using several of these basic ideas mentioned in this chapter to understand aspects of language processing and also how language interacts with vision and memory to give us our cognition. We will see in the later chapters that attentional issues and their involvement with language processing together with visual processing are becoming quite a popular enterprise lately. Lastly, whatever may be the theoretical characterization of attention, this book will argue that no psycholinguistic modelling can be complete without a serious consideration of this baffling phenomena. This we have already started to see in several models of reading, speaking as well as sentence processing. However, it will be seen later, there is a strong urge among language researchers to view many aspects of language processing occurring 'automatically' and therefore attention may not be necessary.

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