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Task probability and report of feature information: What you know about what you 'see' depends on what you expect to need ☆

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ABSTRACT

We investigated the influence of dimensional set on report of object feature information using an immediate memory probe task. Participants viewed displays containing up to 36 coloured geometric shapes which were presented for several hundred milliseconds before one item was abruptly occluded by a probe. A cue presented simultaneously with the probe instructed participants to report either about the colour or shape of the probe item. A dimensional set towards the colour or shape of the presented items was induced by manipulating *task probability* — the relative probability with which the two feature dimensions required report. This was done across two participant groups: One group was given trials where there was a higher report probability of colour, the other a higher report probability of shape. Two experiments showed that features were reported most accurately when they were of high task probability, though in both cases the effect was largely driven by the colour dimension. Importantly the task probability effect did not interact with display set size. This is interpreted as tentative evidence that this manipulation influences feature processing in a global manner and at a stage prior to visual short term memory.

1. Introduction

A major role of attention is to prioritise information received by the senses in accordance with its behavioural significance (Broadbent, 1958). In vision, spatial location seems to be the principal basis on which this attentional prioritisation occurs (Broadbent, 1982; Lamy & Tsal, 2001; Posner, 1980; Tsal & Lavie, 1988). However we can also prioritise by selectively attending to particular *feature dimensions*, e.g. colour, or for items possessing certain values on these dimensions, e.g. red items, (see Adams & Chambers, 2012; Kumada, 2001; Maunsell & Treue, 2006; Rossi & Paradiso, 1995; Stojanoski & Niemeier, 2011; Zhang & Luck, 2009).

Attention, whether towards locations, feature dimensions or values, seems to be intimately linked with conscious visual experience. Indeed, it is argued that attention may be a necessary condition for an observer to demonstrate visual awareness, or at least for awareness of specific details about an object or scene (Dehaene, Changeux, Naccache, Sackur, & Sergent, 2006; Hsieh, Colas & Kanwisher, 2011; O'Regan & Noë, 2001; Posner, 1994; Rensink, O'Regan, & Clark, 1997; though see Lamme, 2003; Koch & Tsuchiya, 2007). The role of attention in visual awareness has been assessed largely through investigation of two phenomena: *change blindness* (Rensink et al., 1997), the striking inability to detect large changes in visual scenes, and *inattentional blindness*, the failure under conditions of misdirected attention to notice the appearance of unexpected objects (Mack & Rock, 1998; Simons & Chabris, 1999). Both phenomena attest to the same principle: that we habitually fail to notice things that would be clearly visible if we knew what to look for and where (Jenson, Yao, Street, & Simons, 2011).

The change blindness phenomenon is most obviously demonstrated in the *flicker paradigm* (Rensink, 2000; Rensink et al., 1997) in which an original version and a modified version of a display or picture (e.g. a jet aeroplane with a missing engine in one version) are presented in a cycling sequence interleaved with a blank screen. Despite actively searching for it, observers typically require several iterations of the cycle to notice changes in the scene. Inattentional blindness is demonstrated using a task in which participants are instructed to monitor a stimulus or set of stimuli (e.g. track some moving circles and count how frequently they cross the horizontal midline); on one critical trial, an unexpected object is introduced (e.g. a red cross moving along the horizontal midline), which participants typically fail subsequently to report even though it passed right in front of their eyes.

Attentional manipulations strongly determine the extent to which changes or unexpected events are noticed. Much of the work looking at the role of attentional allocation in change blindness and inattentional

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blindness has concentrated on spatial attentional manipulations (e.g. Most, Simons, Scholl, & Chabris, 2000; Newby & Rock, 1998; Rensink et al., 1997; Smith & Schenk, 2008; Tse, 2004; Umemoto, Scolari, Vogel, & Awh, 2010). However a body of work has also performed experimental manipulations which influence how observers allocate attention across different stimulus feature values and dimensions. In inattentional blindness, the frequency with which unexpected objects are noticed has been shown to vary according to the type of visual information to which an observer is instructed to attend; unexpected objects are most likely to be noticed by observers when they possess feature values consistent with the attended features of the primary task (Mack & Rock, 1998; Most & Astur, 2007; Most, Scholl, Clifford, & Simons, 2005; Simons & Chabris, 1999). For instance, Most et al. (2005) found that participants viewing a display consisting of moving black and white circles and squares were far more likely to notice the appearance of an unexpected grey circle when they had been instructed to monitor circular objects than when instructed to monitor squares. It seems that when participants had an attentional set for 'circles' this augmented the perceptual salience of the grey circle to a point to which it crossed the awareness threshold (Most et al., 2005).

Comparable effects of attentional set are found in the change blindness literature. Unlike in inattentional blindness, here the observer's attention is typically directed towards an *entire feature dimension*, rather than a particular feature value. It is with such dimensional effects that the current paper is primarily concerned.

The perceptual consequences of manipulations of dimensional attentional set (sometimes referred to as *dimensional weighting*, e.g. Krummenacher & Müller, 2012) are analogous to those described for manipulating attention towards particular feature values. In the change blindness paradigm it has been repeatedly demonstrated that changes are most likely to be noticed when occurring on the stimulus dimension coinciding with the dimensional set of the observer (Aginsky & Tarr, 2000; Austen & Enns, 2000; Austen & Enns, 2003; Beck, Angelone, Levin, Peterson, & Varakin, 2008; Droll, Hayhoe, Triesch, & Sullivan, 2005; Triesch, Ballard, Hayhoe, & Sullivan, 2003; van Lamsweerde & Beck, 2011; Wegener, Ehn, Aurich, Galashan, & Kreiter, 2008). For example, if in the flicker task participants are cued that a change will involve an item's colour, they are more efficient in spotting such changes against a baseline where either no cue or invalid cue information is given prior to the trial (Aginsky & Tarr, 2000; Wegener et al., 2008).

Similar effects in change blindness can also be found by inducing a dimensional set in a less directed manner, by varying the demands of a primary task given concurrently with the change detection task (Droll et al., 2005; Triesch et al., 2003), or by manipulating the probabilities with which different sorts of change occur across experimental trials (Austen & Enns, 2000; Austen & Enns, 2003; Beck et al., 2008; van Lamsweerde & Beck, 2011). Using the flicker paradigm Austen and Enns (2000, 2003), induced a dimensional set by having certain changes occur with a higher probability in an experiment, the type of higher probability change being varied across participant groups. Changes tended to be detected most efficiently when they were consistent with the dimensional set presumably induced by the trial probability manipulation. For instance, with face stimuli participants who mostly received trials in which the change occurred in the identity of a face stimulus were more efficient at detecting identity changes than they were at detecting changes in facial expression. Participants experiencing mostly changes in facial expression displayed an effectively converse pattern of results.

Similar *change probability* effects have also been reported for simple visual objects such as coloured geometric shapes (Beck et al., 2008; van Lamsweerde & Beck, 2011). van Lamsweerde and Beck (2011) used a one-shot change detection task in which displays consisting of several such shapes were presented interleaved by a blank field; the two displays were the same apart from a change either to the colour, shape or location of one of the items. An attentional set was induced by giving participants an initial block of trials in which one type of change was more frequent than the other two. For three groups of participants either colour, shape or location changes occurred most frequently. Change detection was then measured in a subsequent trial block in which each type of change occurred equally often. Change detection was measured across all trials by the ability to identify the changed object in the post-change display. Results indicated that change detection was governed largely by participants' experiences of change probability in the preceding trial block, participants generally being more accurate in reporting the type of change presented most frequently in this initial block[1].

Thus, findings from both the change blindness and inattentional blindness literatures are consistent with attentional set influencing what we *know* about what our eyes tell us. How might such influence occur? Where attention is being directed to a single feature value it is possible that spatial attention may play a mediating role in determining performance. Such claims have been made in the context of findings from visual search (Shih & Sperling, 1996; Moore & Egeth, 1998; cf. Andersen, Müller, & Hillyard, 2009), the argument being that cueing a feature value serves to direct attention to locations containing that particular feature. A similar mechanism could account for some of the earlier described findings. For instance in the work of Most et al. (2005) on inattentional blindness, inducing an attentional set for 'square' items might influence the distribution of spatial attention in a way that it becomes biased towards locations where objects possessing this feature are currently located. Were this the case the sudden appearance of an unexpected item which also possessed this feature value would increase the likelihood that such an item received some spatial attention and, consequently, increase the probability of it being consciously perceived.

Even where task conditions direct an observer towards an entire feature dimension spatial attention could sometimes play a mediating role. Indeed, Austen and Enns (2003) interpret their effect as a consequence of differential spatial filtering of the stimuli used. Feature dimensions such as face identity and face emotion are often prominent at different scales of spatial frequency (e.g. Schyns, Bonnar, & Gosselin, 2002); it is thus plausible that when task conditions emphasise a particular feature of these stimuli that there is a corresponding change in the scale at which spatial attention operates leading to differences in change detection performance.

However other findings cannot have arisen via spatial attention, however conceived; for instance, in the earlier described study of van Lamsweerde and Beck (2011) the manipulated feature dimensions (colour and shape) were not ones which can be selected by spatial filtering. How else could such effects of dimensional set manipulation arise? van Lamsweerde and Beck (2011) give two possible interpretations of their results, whilst also noting that their data could not distinguish between them. One possibility they offer is that dimensional set influences the sort of information about object features which is selectively encoded in visual short term memory (VSTM). A further possibility is that dimensional set influences not feature representation itself but the order in which feature information is compared across the pre- and post-change representations: a change being more likely to be detected if it is present in the initial comparison process because the representation will be less subject to decay.

To summarise, there is clear evidence that dimensional set influences the accuracy of change detection. What is less clear is the basis of these effects and, more specifically, whether the visual representations themselves are influenced. Two experiments explore this question further by determining what influence dimensional set has on what observers can explicitly report about the features of objects

[1] The authors report effects for both colour and shape dimensions but not for location. They argue that location may have a special role as a stimulus dimension and may be a default component of object representations irrespective of shifts in feature-based attention.