Acta Psychologica 142 (2013) 168–176

Contents lists available at SciVerse ScienceDirect

Acta Psychologica

journal homepage: www.elsevier.com/ locate/actpsy

Semantic consistency versus perceptual salience in visual scenes: Findings from change detection

Sara Spotorno [a,b,*], Benjamin W. Tatler [b], Sylvane Faure [c]

[a] Dipartimento di Scienze della Formazione, University of Genoa, Corso Podestà 2, 16128 Genoa, Italy
[b] School of Psychology, University of Dundee, Park Place, Dundee DD1 4HN, Scotland, UK
[c] Laboratoire d'Anthropologie et de Psychologie Cognitives et Sociales, University of Nice–Sophia Antipolis, Campus Saint-Jean-d'Angély/SJA3/ISHSN, 3 Boulevard François Mitterrand, 06357 Nice Cedex 4, France

ARTICLE INFO

Article history:
Received 28 February 2012
Received in revised form 10 December 2012
Accepted 20 December 2012
Available online 19 January 2013

PsycINFO classification:
2300 Human Experimental Psychology
2323 Visual Perception
2346 Attention

Keywords:
Change detection
Diagnosticity
Semantic inconsistency
Probability of occurrence
Perceptual salience

ABSTRACT

In a one-shot change detection task, we investigated the relationship between semantic properties (high consistency, i.e., diagnosticity, versus inconsistency with regard to gist) and perceptual properties (high versus low salience) of objects in guiding attention in visual scenes and in constructing scene representations. To produce the change an object was added or deleted in either the right or left half of coloured drawings of daily-life events. Diagnostic object deletions were more accurately detected than inconsistent ones, indicating rapid inclusion into early scene representation for the most predictable objects. Detection was faster and more accurate for high salience than for low salience changes. An advantage was found for diagnostic object changes in the high salience condition, although it was limited to additions when considering response speed. For inconsistent objects of high salience, deletions were detected faster than additions. These findings may indicate that objects are primarily selected on a perceptual basis with subsequent and supplementary effect of semantic consistency, in the sense of facilitation due to object diagnosticity or lengthening of processing time due to inconsistency.

1. Introduction

Many studies in recent decades have revealed the striking difficulty that observers encounter when attempting to detect a visual change if its local transient signal is unavailable (see Rensink, 2002). In such situations, it is necessary to draw attention effortfully to the changed region and compare pre- and post-change representations.

Attentional selection and memory processes depend, to a great extent, on the perceptual and semantic properties of the changes. Detection can be easier for changes that are visually salient (in terms of low level features, such as brightness, colour or orientation: Pringle, Irwin, Kramer, & Atchley, 2001; Spotorno & Faure, 2011a, 2011b), although studies do not provide unequivocal evidence on this issue (see Stirk & Underwood, 2007). Contextual meaning and semantic relations within a scene can also play a substantial role when allocating attention toward the changes and in enhancing memory. While there is a broad consensus on the importance of semantics for change detection and scene viewing, there is disagreement about the possible nature of semantic effects (e.g., Hollingworth & Henderson, 2000). We shall now consider evidence for the influence of both perceptual and semantic properties on scene processing and change detection.

1.1. Semantic consistency in change detection

Several studies have shown an advantage for detecting changes that involve the most consistent objects in the scene (Auvray & O'Regan, 2003; Kelley, Chun, & Chua, 2003; O'Regan, Deubel, Clark, & Rensink, 2000; Pringle et al., 2001; Rensink, O'Regan, & Clark, 1997, 2000). These highly semantically consistent objects are often considered to be of "central interest" to the scene in that they can be attributed to the scene context from a brief glimpse (i.e., the gist; see Friedman, 1979; Oliva, 2005). Changes to central interest objects are easier and faster to detect than changes to "marginal interest" objects, which are not relevant for the gist of the scene. These results have been interpreted as implying that objects which are highly consistent with the scene gist are prioritised for attentional orientation and selection (e.g., Rensink et al., 1997). Attentional prioritisation of objects that are highly consistent with or predictable from the scene gist is supported by a variety of recent studies. For example, the accessibility of individual item information depends upon the background context of the scene (e.g., Davenport, 2007; Davenport & Potter, 2004; Torralba, 2003) as well as object-to-object

* Corresponding author at: Active Vision Lab, School of Psychology, Park Place, University of Dundee, Dundee DD1 4HN, UK. Tel.: +44 1382 384683; fax: +44 1382 229993.
E-mail address: s.spotorno@dundee.ac.uk (S. Spotorno).

0001-6918/$ – see front matter © 2013 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.actpsy.2012.12.009

context, that is spatial and semantic relationships across items (e.g., Brooks, Rasmussen, & Hollingworth, 2010; Davenport, 2007).

While the above studies indicate attentional prioritisation of semantically consistent objects (see also De Graef, Lauwereyns, & Verfaillie, 2000), others indicate that semantically inconsistent objects or changes may be prioritised (Gordon, 2004, 2006; Hollingworth & Henderson, 2000, 2003; Stirk & Underwood, 2007). Prioritisation may involve differences in attentional engagement in which early partial recognition of objects within the scene is sufficient to determine violations of gist and, as a consequence, to direct attention toward inconsistent objects (e.g., Bonitz & Gordon, 2008; Loftus & Mackworth, 1978; Underwood & Foulsham, 2006; Underwood, Templeman, Lamming, & Foulsham, 2008). However, several authors have failed to find evidence for this possibility (e.g., De Graef, Christiaens, & d'Ydewalle, 1990; Gareze & Findlay, 2007; Võ & Henderson, 2011). Alternatively, attentional prioritisation of inconsistent objects may involve differences in attention disengagement from objects: inconsistent objects are selected on bases other than semantics (i.e., either incidentally or because of their perceptual salience) and attention is maintained longer on them than on consistent objects (see Henderson & Hollingworth, 1999). Whichever account of the attentional effect of inconsistency is adopted, the performance advantage of inconsistency in change detection has been explained in terms of better maintenance of memory representations. This advantage could be due to greater engagement of attentional resources and deeper processing necessary to identify inconsistent objects (e.g., Biederman, Mezzanotte, & Rabinowitz, 1982; Boyce, Pollatsek, & Rayner, 1989; Davenport, 2007; Davenport & Potter, 2004; Gordon, 2006; Hollingworth & Henderson, 2000, 2003), or to attempt to solve the cognitive conflict determined by the gist violation (e.g., Gordon, 2004; Loftus & Mackworth, 1978). It must be noted, however, that these studies compared highly inconsistent objects (e.g., a fire hydrant in a living room) to consistent but marginally meaningful objects for the gist of the scene (e.g., a chair in a kitchen where there were other pieces of furniture, none of which was crucial for the gist).

Overall, a variety of studies have provided evidence for an attentional prioritisation of both objects that are highly consistent and objects that are highly inconsistent with scene semantics (but see e.g. Hollingworth & Henderson, 1999, for different findings). These findings are not necessarily contradictory because highly consistent (or inconsistent) objects are compared to objects that are consistent but of low relevance to the scene's gist. It is, therefore, entirely plausible that both highly consistent and highly inconsistent objects might receive attentional priority. What we cannot discern from the literature reviewed above is the relative prioritisation for highly consistent versus highly inconsistent objects in scenes. For this purpose, direct comparison between these two types of objects in the same study is needed.

One potential issue when comparing the priority that objects are given on the basis of their semantics is that different objects will typically differ also in terms of their perceptual characteristics and how conspicuous they are relative to their scene background. Thus, it is important to consider the consequences of varying perceptual properties of objects on change detection and scene perception.

1.2. Perceptual properties in change detection

Whether the perceptual properties of an object influence attentional priority is the topic of much current debate. Some support for the notion that overt selection correlates with visual conspicuity, or visual salience (Itti & Koch, 2000) has been found in scene viewing studies (e.g., Mannan, Ruddock, & Wooding, 1997; Parkhurst, Law, & Niebur, 2002; Reinagel & Zador, 1999). However, other authors argue that this correlation need not imply a causal link between perceptual salience and fixation selection (Carmi & Itti, 2006, Henderson, Brockmole, Castelhano, & Mack, 2007; Tatler, Baddeley, & Gichrist, 2005), and favour accounts of fixation selection based on higher-level factors (see Tatler, Hayhoe, Land, & Ballard, 2011 for a review).

Foulsham and Underwood (2007) argued that the influence of perceptual factors on attention is likely to emerge when the whole picture has to be encoded, and not when the observer has to look for a target category or a specific item. The impact of salience might thus be greater in change detection paradigms than in studies on visual search. Indeed there is evidence for better or faster change detection for objects of high perceptual salience, either in conditions of overt (Pringle et al., 2001) or covert (Spotorno & Faure, 2011a, 2011b) attention. In contrast, Stirk and Underwood (2007) reported no effect of visual salience on change detection latencies in a flicker paradigm, where the original and the modified scenes are repeated several times per trial. Thus it is unclear how perceptual salience influences perception of visual changes.

1.3. The interplay between perceptual and semantic properties in change detection

Most authors argue that the allocation of attention during scene perception is likely to be guided by both low-level perceptual and higher-level information. It is less clear how perceptual salience and semantic properties might be related.

Some recent evidence in this respect indicates that the two dimensions act independently (Kollmorgen, Nortmann, Schröder, & Köning, 2010). If this is the case, we might expect that highly salient changes would be better detected irrespective of their semantic properties, and that an advantage due to semantics would be found irrespective of the salience of the change.

Other findings favour instead an interaction between perceptual and semantic aspects in determining attentional allocation. However, the nature of this possible interplay is still an issue of debate. Three major accounts have been proposed.

The first account claims that high- and low-level factors interact, but semantic information is prioritised. For instance, Nyström and Holmqvist (2008) found an effect of salience only for images with rather neutral semantics (trees, leaves, etc.), whereas in images containing semantically relevant regions (i.e., faces or man-made elements) attention was mainly allocated to these informative regions, even when they were of low salience. Scene schema knowledge and memory for similar viewing episodes seem to have crucial roles (e.g., Henderson et al., 2007) in this cognitive dominance for controlling attention. If this is the case, we might expect that when objects are either highly consistent or highly inconsistent, this strong semantic component will override any effect of salience.

Second, the interaction between perceptual salience and semantics might favour salience. Several studies on visual search and scene memory (Underwood & Foulsham, 2006) or on visual change detection (Pringle et al., 2001; Spotorno & Faure, 2011a), that have attempted to manipulate orthogonally both perceptual salience and semantic properties, support this possibility. They reported, indeed, that the effect of semantic informativeness, in terms of either high inconsistency (Underwood & Foulsham, 2006) or high consistency (Pringle et al., 2001; Spotorno & Faure, 2011a), may be absent – or at least reduced – if the object is highly salient, but present – or larger – for low salience objects. Furthermore, they also revealed that perceptual salience may have less effect on change detection performance when objects are highly consistent (i.e., highly important in defining gist) than when they are consistent to some extent with the type of scene but only scarcely informative for gist.

Finally, the notion of perceptual salience as an attentional guide has recently been recast as a potential mechanism for detecting unexpected or surprising events or objects (Itti & Baldi, 2009). If perceptual salience is an important indicator of violations of expectation, then we might hypothesise salience-based effects to be prominent for objects that are highly inconsistent with scene gist (and are thus 'surprising') but absent or reduced for objects that are highly consistent with scene gist. Similarly, we might hypothesise that highly inconsistent changes are better detected than consistent ones only when their perceptual salience is strong.