



Visual responses to action between unfamiliar object pairs modulate extinction

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ABSTRACT

Previous studies show that positioning familiar pairs of objects for action ameliorates visual extinction in neuropsychological patients (Riddoch, Humphreys, Edwards, Baker, & Willson, 2003). This effect is stronger when objects are viewed from a self-perspective and are placed in locations congruent with the patient's premorbid handedness (Humphreys, Wulff, Yoon, & Riddoch, 2010a), consistent with it being modulated by a motor response to the stimuli. There is also some evidence that extinction can be reduced with unfamiliar object pairs positioned for action (Riddoch et al. 2006), but the effects of reference frame and hand-object congruence have not been examined with such items. This was investigated in the present experiment. There was greater recovery from extinction when objects were action-related compared to when they were not, in line with previous studies. In addition, patients benefited more when they saw action-related pairs from a third-person than from a first-person perspective. Interestingly, on trials where extinction occurred, there was a bias reporting the 'active' object on the extinguished side—a reversal of the standard pattern of extinction—but only when objects were seen from a self-perspective. The data show that several factors contribute to the effects of action relations on attention, depending upon the familiarity of the object pairs and the reference frame that stimuli have been seen in.

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1. Introduction

Visual extinction, a neuropsychological disorder of spatial attention, can disrupt the ability of patients to report items in complex, multi-stimulus displays. Extinction is commonly found after damage to the (right) posterior parietal cortex and is characterised by the failure to detect a contralesional stimulus accompanied simultaneously by an ipsilesional stimulus (Chechlacz et al. (in press); Driver & Vuilleumier, 2001; Karnath, 1988). Several behavioural studies have demonstrated that, despite the lack of report, there is evidence that contralesional stimuli are processed. Notably, the relations between the contralesional and ipsilesional stimuli affect extinction, with extinction reduced when these stimuli group together. There is now evidence for a wide variety of grouping cues being effective in reducing extinction. Extinction can be modulated by grouping on the basis of Gestalt principles such as similarity and contrast polarity (e.g., Gilchrist, Humphreys, & Riddoch, 1996), by stored knowledge about familiar shapes (Ward, Goodrich, & Driver, 1994) and by lexical identity (Kumada & Humphreys, 2001).

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Patients are also able to overcome their pathological bias to favour the ipsilesional stimulus when the stimulus itself affords an action. For example, di Pellegrino, Rafal, and Tipper (2005) demonstrated that patients showed less left visual extinction when the handle of a contralesional cup afforded a left-hand rather than a right-hand grasp. They proposed that the observation of a handle results in an automatic activation of motor programs to reach and grasp the object that, in turn, biases visual selection and stimulus detection. Interestingly, affordance effects in extinction patients have been reported not only for single objects (e.g., di Pellegrino et al., 2005) but there is also evidence for effects of action relation between objects. For example, Riddoch et al. (2003) first showed that positioning objects for action reduced extinction in patients with parietal lesions. Riddoch et al. presented two objects (e.g. a paint pot and a paintbrush) either positioned to interact with each other (the paintbrush about to dip into the paint pot) or not (the paintbrush facing away from the paint pot). Extinction was less severe when objects appeared in the correct positions for action, whereas there was no recovery from extinction when the same objects were positioned incorrectly for action. Riddoch et al. proposed that familiar objects co-positioned for action were grouped together as a unitary configuration. The objects could then be selected as a single perpetual unit even when one fell in the contralesional field

and would be otherwise subject to extinction. Consistent with this argument for configural coding of action-related stimuli, Riddoch et al. (2011) reported that the effects of action relations were disrupted if manipulations were introduced to disturb configural coding, such as inverting the stimuli or alternating their relative sizes. In addition, the effects were not semantic in nature, because no benefits on extinction were found with pairs of objects that were associatively-related (e.g., tin and can) rather than action-related (Riddoch et al., 2003).

One other interesting result reported by Riddoch et al. (2003) concerned performance on extinction trials, when patients only reported one of the two object presented. Standardly patients are biased to report the ipsilesional stimulus on these trials. Riddoch et al. found an exception to this, when objects were positioned to interact together. With these stimuli Riddoch et al. reported preferential report of the active member of the pair (the object that would be used on the other item), irrespective of whether it fell in the contralesional or ipsilesional field. Thus, on trials where the active object fell in the contralesional field patients reported the contralesional stimulus more often than the ipsilesional stimulus – that is, there was a reversal of the standard spatial extinction effect. Riddoch et al. suggested that patients could implicitly code the presence of an interacting pair of objects and, with some stimuli, attention was cued first to the active member of the pair. This led to this item being preferentially reported on trials where extinction occurred. Converging evidence for attention being drawn to the active member of an interacting pair comes from Roberts and Humphreys (2010b) who used a measure of ‘prior entry’ on temporal order judgements.

These results with interacting objects are of considerable interest since they indicate that visual attention is sensitive not only to low-level perceptual regularities (e.g., collinearity between edges) but also to higher-level regularities based on the co-occurrence of objects in action (see Riddoch et al., 2011). However, the underlying factors and processing mechanisms that determine these effects remain poorly understood. For example, are the effects based on the perceptual familiarity of object pairs, on perceptual coding of action or on associated motor responses that may be evoked by pairs of interacting objects?

There is evidence that the perceptual familiarity of the object pairs themselves is not critical. Riddoch et al. (2006) used object pairs with a low frequency of co-occurrence but which were positioned to interact together. They again found recovery from extinction. The presence of the action relation alone seemed important here. Evidence for perceptual sensitivity to these action relations comes from Roberts and Humphreys (2010a), who examined brain activity when participants viewed objects co-located or not co-located for action. These investigators found enhanced activity in visual cortical regions (e.g., the lateral occipital cortex and the fusiform gyrus) when objects were co-located for action compared with when they were not co-located for action. The results are consistent with action-related objects yielding an enhanced perceptual response.

On the other hand, there is also evidence for motor-related responses in relation to action-based properties of images. For instance, Kumar, Yoon and Humphreys (2012) reported early activity over motor cortex (N1 component) when participants viewed images of objects being grasped correctly relative to when they were grasped incorrectly for action. Neuropsychological evidence comes from Humphreys et al. (2010a) who presented familiar pairs of objects to patients showing visual extinction. The objects were either positioned correctly for action or reflected so that they were positioned incorrectly. In addition, the active member of the pair could be aligned with the patients premorbidly dominant hand or not, and the stimuli were depicted either from a first-person perspective (in the patient’s own reference

frame) or from a third-person perspective (as if seen from the opposite side of a table). Humphreys et al. found that recovery from extinction was stronger when the objects were held in hands congruent with the premorbidly dominant hand for the patient. This effect was enhanced when the objects were seen from a first-person compared to a third-person perspective. The effect of hand-alignment suggests that action-related objects may evoke a stronger motor response than action-unrelated objects. This response may be particularly potent when the stimuli are presented in a first-person perspective, consistent with visuo-motor coupling driving attention to action-related objects (Humphreys et al. 2010b; see also Valyear, Gallivan, McLean, & Culham, 2012, for fMRI evidence).

In the present study we extended this prior result by examining whether these visuo-motor responses are sensitive only to the implied action, when objects are co-located for action, or also to the visual familiarity of the object pairs. To do this, we replicated the procedure of Humphreys et al. (2010a), but this time used pairs of objects not normally used together and so not familiar as a pair. Is the mere presence of an action, between objects paired for action, sufficient to alleviate the contralesional attentional deficit in extinction patients, even if the objects are not usually used together? Also, if an effect is found, is it visual or motor-related (e.g., is there a visual effect of the reference frame or a motor-based effect determined by whether the objects align with the patient’s premorbidly dominant hand)? We assessed whether these factors modulated the ability of the patients to report both objects on a two-object trial, and also whether they influenced attention to objects within a pair, on extinction trials (Riddoch et al., 2003). To maximise the action effects, we showed objects grasped by a hand that was congruent with the action normally performed with the object. Previous studies have shown that the presence of the hand grasp maximises affordance-based responses to objects (e.g., Kumar et al., 2012).

2. Methods

2.1. Patients

Ten brain-damaged patients with visual extinction, comprising two females and eight males from 39 to 78 years of age ($M=67.70$; $S.D.=11.63$), were recruited from the volunteer panel at the School of Psychology, University of Birmingham. Five patients (JB, MC, MP, TH, and TM) had right unilateral lesions, three (DT, PH, and RH) had left unilateral lesions, and two (PF and PM) had bilateral lesions (clinical details are given in Table 1, and lesion reconstructions are shown in Fig. 1). Seven patients showed left visual extinction, and the remaining (DT, PH, and RH) showed right visual extinction. Since the terms ‘ipsilesional’ and ‘contralesional’ are misleading in the case of bilateral lesions, we use instead the terms ‘non-extinguished’ and ‘extinguished’, respectively. Patients did not have visual field defects on visual confrontation testing. None of those patients suffered from optic ataxia. Four patients (JB, PF, PM, and RH) had a clinically defined problem in gesture recognition (1 patient), gesture production (2 patients) or imitation (2 patients) on the BCoS Cognitive Screen (Humphreys, Bickerton, Samson, & Riddoch, 2012). However the extinction data for these patients were not clearly different from the results of the other patients. All except four (JB, MP, RH, and TH) were right-handed as tested by the Edinburgh Handedness Inventory (Oldfield, 1971). All reported normal or corrected-to-normal vision. Informed consent was obtained from all patients and the study was approved by a national NHS research ethics committee. The experiment was conducted over a period from November 2009 to March 2012. Each patient’s performance was relatively stable across this period.

2.2. Apparatus and stimuli

Thirty-two coloured photographs of common objects the same as those in Humphreys et al. (2010a) were used. Each item was depicted grasped by a hand and held above a table, photographed from a first-person perspective and from a third-person perspective. The individual items for each perspective were combined into 16 object pairs that were not commonly used together (e.g., paint pot and bottle opener; see Fig. 2(a and b) for the first-person and the third-person

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