Perception, 2011, volume 40, pages 1154 – 1163

doi:10.1068/p6974

An advantage for active versus passive aperture-viewing in visual object recognition

Matt Craddock
Institut für Psychologie I, Universität Leipzig, Seeburgstrasse 14 – 20, 04103 Leipzig, Germany; e-mail: matt.craddock@uni-leipzig.de; also School of Psychology, University of Liverpool, Liverpool L69 3BX, UK

Jasna Martinovic
School of Psychology, University of Aberdeen, Aberdeen AB24 2UB, UK

Rebecca Lawson
School of Psychology, University of Liverpool, Liverpool L69 3BX, UK
Received 30 March 2011, in revised form 27 September 2011

Abstract. In aperture viewing the field-of-view is restricted, such that only a small part of an image is visible, enforcing serial exploration of different regions of an object in order to successfully recognise it. Previous studies have used either active control or passive observation of the viewing aperture, but have not contrasted the two modes. Active viewing has previously been shown to confer an advantage in visual object recognition. We displayed objects through a small moveable aperture and tested whether people's ability to identify the images as familiar or novel objects was influenced by how the window location was controlled. Participants recognised objects faster when they actively controlled the window using their finger on a touch-screen, as opposed to passively observing the moving window. There was no difference between passively viewing again one's own window movement as generated in a previous block of trials versus viewing window movements that had been generated by other participants. These results contrast with those from comparable studies of haptic object recognition, which have found a benefit for passive over active stimulus exploration, but accord with findings of an advantage of active viewing in visual object recognition.

1 Introduction

There are many circumstances in which an entire object cannot be seen clearly with a single glance or fixation. Even when the whole of an object is visible, multiple fixations on different details may be necessary to see them with sufficient clarity to recognise the whole. Furthermore, it is not necessary to see the whole object at once to recognise it: partially occluded objects can also often be identified (eg Vrins et al 2009). Consider, also, haptic recognition of objects (eg Craddock and Lawson 2008; Klatzky et al 1985). The effective field-of-view of the finger is much smaller than that of the eye, and haptic recognition is accomplished through a succession of exploratory movements (eg Lederman and Klatzky 1987). Thus, we are capable of integrating sequentially explored object regions over both time and space.

One method of examining this capability is aperture viewing, in which the field-of-view of vision is restricted such that only a small area of an object is visible at any given time. We can still perceive objects behind such an aperture as unified wholes. For example, when a line drawing is passed behind a narrow slit, observers report seeing a complete object despite only a limited portion of the object being visible at a given time (Parks 1965). Thus, the experience of seeing an object as complete can be distinguished from seeing the whole object at once. Parks (1965) argued that this was evidence of post-retinal visual storage, a process of extracting individual parts of an object and reconstructing them with the appropriate spatial configuration. The qualities of the resulting percept of that shape may depend upon a variety of factors, such as the velocity of the movement of the aperture over the object or the object behind the aperture (eg Anstis and Atkinson 1967; Haber and Nathanson 1968; Morgan et al 1982).

Nevertheless a situation in which a narrow aperture remains stationary, with an object moving behind it, is quite unlike one in which a percept may be built up from multiple successive but discontinuous fixations. Hochberg (2007 [1968]) described such a process as the building of a schematic map, which he defined as "The program of possible samplings of an extended scene, and of contingent expectancies of what will be seen as a result of those samplings". He gave the example of an aperture moving around the boundary of a cross. Given an appropriate sequence of images as the aperture moves, and knowledge of the concept of a cross, the observer would be able to interpret the individual contours seen through the aperture as belonging to a cross.

Girgus et al (1980) showed participants line drawings of simple shapes through an aperture that either systematically traced or moved randomly along the contours of those shapes. Shape recognition was impaired when the aperture moved randomly. Girgus et al argued that shape recognition in such circumstances is accomplished by a hypothesis-testing procedure. Systematic movement allowed people to anticipate what they would see and then to test whether the actual input matched the anticipated input. If part of a recognisable object is seen, using an appropriate schematic map may aid recognition by raising the expectation that other parts may be found in a particular spatial configuration. In contrast, with random movement, one must use evidence as and when it becomes available.

More recently, Króliczak et al (2003) contrasted aperture movement, in which an aperture moves over a stationary object, and object movement, in which an object moves behind a stationary aperture. They found that exploration using a movable aperture more closely followed the structure and contours of the object than exploration by moving the object behind the aperture. Furthermore, subsequent old – new recognition of the objects presented in full (ie without the aperture) was better in the aperture-movement than in the object-movement condition. Króliczak et al argued that, because the object was stationary in the aperture-movement condition, its position with respect to a frame of reference was always known. Thus, information about the extent of the movement of the aperture and concomitant shifts in gaze direction also provided information about the real size and spatial arrangement of the object and its parts. In contrast, in the object-movement condition shifts in gaze direction were absent since the aperture remained fixed. Here, participants typically spent more time studying the centre of the object, suggesting that they may have used it as a reference point. Moving the object would also move the reference point, and participants would have to keep track both of the shifting reference point and the extent of their movement.

As Króliczak et al (2003) observe, previous aperture viewing experiments have mostly used passive paradigms, in which the movement of the object or aperture was controlled by the experimenter rather than the participant (eg Haber and Nathanson 1968; Hochberg 2007 [1968]; Rock 1981). Several authors have found evidence that recognition of novel objects is facilitated by active viewing in comparison to passive viewing (eg Harman et al 1999; James et al 2001, 2002). All of these authors attributed the advantage for active over passive exploration as arising from participants focussing their exploration on more informative views of the objects. Such informative regions may be defined by relatively low-level factors, such as salience (eg Itti and Koch 2000), or by specific object parts, such as the head of the hammer. However, these studies all used rotation of a 2-D object around its axes to allow viewing from different angles, which may differ from active exploration of a stationary object seen from a fixed viewpoint. Nevertheless, a similar advantage might obtain for active control of aperture viewing even with fixed views of objects, since it would also allow participants to focus on informative regions of objects. However, Króliczak et al did not directly compare active control to passive viewing of aperture or object movements.

Furthermore, during aperture viewing visual object recognition may operate under the same constraints as some kinds of haptic object recognition: Loomis et al (1991) found that, when the visual field-of-view was restricted to the width of a fingertip, visual recognition of raised line drawings was as slow as haptic recognition of such drawings, which typically takes around 10 s longer than visual recognition of raised line drawings without such field-of-view restrictions (Lawson and Bracken 2011). Similar to Króliczak et al's results, performance was better when the aperture moved over a stationary object than when the object moved behind a stationary aperture.

Additionally, the aperture movements are controlled by hand. The distinction between active and passive modes of exploration is well established in touch (Gibson 1962; see Symmons et al 2004 for a review). Magee and Kennedy (1980) investigated the recognition of raised-line drawings by blindfolded sighted participants. Participants whose finger movements were guided around the drawings by an experimenter successfully identified more of the drawings than participants who actively controlled their finger movements. Furthermore, performance was better when participants' fingers were traced over the outline of the drawing than when the drawing was moved under a stationary finger, comparable to the contrast between aperture movement and object movement in previous experiments (Króliczak et al 2003; Loomis et al 1991). D'Angiulli et al (1998) also found an advantage for passive exploration of raised-line drawings for blindfolded sighted children. Magee and Kennedy (1980) suggested that the additional processing demands of planning and executing movements may disadvantage active relative to passive haptic exploration because of the limited processing resources of the haptic system.

In contrast, Richardson et al (1981) suggested that it is specifically the planning of movements rather than their execution that results in an advantage for passive exploration, and thus that such performance reflects cognitive rather than haptic limitations per se. Richardson et al (1981) compared active versus passive exploration in a haptic path-learning task. Participants learned to follow a raised-line path, while either actively controlling their movements or being passively guided along it. In one condition, the path was embedded in a maze during learning; thus, active participants had to choose a direction at branches along the path, whereas passive participants simply followed the guiding movements. In another condition, the path was not embedded in a maze during learning, and thus participants did not have to decide which direction to take at branches in the path. In both conditions, participants subsequently had to follow that path through a maze. When the active participants had to make decisions about the directions they would take while learning the path, they performed worse than passive participants. However, when they did not have to make such decisions, they performed as well as passive participants. Thus, evidence from haptic tasks that are similar to aperture viewing tasks suggests that active aperture viewing may be worse or as good as passive viewing, while visual object recognition literature suggests that active viewing should be better than passive viewing. Previous aperture viewing experiments have not directly contrasted active versus passive aperture viewing.

To examine these differences, we designed an experiment in which participants first performed a block of trials in which their task was to decide if an object was familiar and nameable or unfamiliar and unnameable while actively controlling a viewing window. The same task was used in a second block. However, here separate groups either actively controlled a viewing window in order to examine an object, or passively observed a viewing window which replicated previously recorded movements made during exploration of the same object by either themselves in a preceding block or by a different observer.

Each object was shown against a standard background and was obscured by an ellipse in order to indicate its approximate location while concealing its identity. The ellipse ensured that participants explored the object rather than the background.

Previous aperture viewing experiments, such as those of Parks (1965) and Króliczak et al (2003), presented objects in isolation, with no background. Here, participants may have had to use the boundaries of the experimental apparatus as a frame of reference for their object explorations, as suggested by Króliczak et al. Our background provided a richer frame of reference and some information about the real size and shape of objects.

If planning of the direction and extent of movements associated with controlling the moving window interferes with the recognition process, then participants should perform better when recognising objects through a passively viewed moving window compared to when they actively controlled the window. Additionally, if the predictability of what will be seen following an aperture movement, or if the specific sequence of movements made is encoded during exploration, then participants may show an advantage when viewing replays of their own movements as opposed to those of another participant. By replaying the same movements to two groups, the same perceptual information is made available at the same rate to those groups, and any difference in performance would be attributable to the self-versus-other-produced movement pattern. Alternatively, if active exploration provides more direct feedback on the size and spatial location of an object's contours, then recognition may be better when the aperture movements are directly controlled.

2 Method

2.1 *Participants*

Forty-five participants (twelve male) from the University of Liverpool were recruited in return for course credit. Ages ranged from 18 to 34 years ($M = 19.6$ years, SD = 3 years). Forty-two participants were right-handed, three left-handed.

2.2 *Stimuli*

Stimuli were grey-scale photographs of 80 real objects. 40 objects were familiar (see Appendix for list of names and supplementary materials for photographs), and 40 were unfamiliar (see supplementary materials for photographs). The unfamiliar objects were created by glueing together parts of real objects, by dismembering real objects, or were objects that would not usually be seen or felt, such as rarely encountered tools. The objects provided a broad variety of shapes and sizes. A further 10 photographs of objects were used as practice items. Each object was glued to a 20 cm^2 ceramic wall tile, and was photographed along the approximate line-of-sight of a seated viewer. All objects were photographed with the same background and environmental context (see figure 1a). The photographs were scaled, such that the objects subtended approximately the same visual angle when presented on the touch-screen monitor as they would do when seen in real life from the same angle and distance. A second set of images was produced in which the photographs were blurred[(1)] and then the objects obscured by an elongated black shape along their main axis of elongation (see figure 1b).

2.3 *Design and procedure*

Participants sat approximately 40 cm in front of a 15 inch touch-screen (ELO Touchsystems). Each trial began with a fixation cross. Participants touched the cross to begin. Participants then saw a blurred image showing an object and displayed at a resolution of 1024×768 pixels, with a square aperture initially centred at the fixation cross. The image was not blurred within the boundaries of this aperture (see figure 1c). The participant's task was to decide if the object was familiar or unfamiliar. They pressed the 'space' key as soon as they had made their decision, then typed 'f' or 'u' for familiar and unfamiliar objects, respectively, and finally typed in the name of the object for familiar responses or 'UNF' for unfamiliar responses.

(1) These were produced using the GNU Image Manipulation Program (http://www.gimp.org). A Gaussian blur with a radius of 6 pixels was applied to all images.

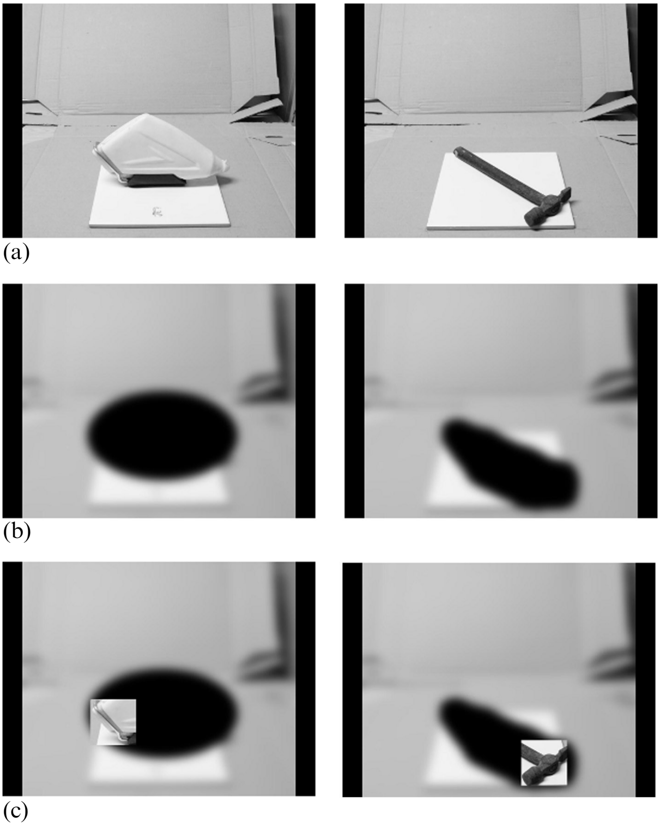

Figure 1. Images of an unfamiliar object (left column) and a familiar object (a hammer; right column) with (a) the original image of the scene; (b) a blurred version of the original image with a black ellipse covering the object; (c) the image shown in the experiment with a square moveable aperture revealing a non-blurred part of the original image.

Participants were allocated to three groups of fifteen: *active*, *passive-self*, and *passive-other*. All three groups performed the same task in the first block, actively controlling the movement of the viewing aperture using the index finger of their right hand while examining the object. Participants were instructed to use smooth finger movements to guide the aperture, and avoid lifting their finger from the screen. They found this an easy and intuitive way to interact with the image. To prevent the participants' hands obscuring the image during exploration, the lower boundary of the window was drawn 15 pixels above the participant's finger. Participants first completed 10 active practice trials with the window fixed at 100 $pixels^2$ throughout. They then completed a block of 80 active trials in which the size of the window varied from an initial size of 50 $pixels^2$. This size was usually sufficient to prevent participants from being able to see the whole of any given object at once. Their finger location was recorded as x and y coordinates every 25 ms. After every 5th trial, the mean RT of the preceding 5 trials was checked. If it fell outside the specified upper (6000 ms) or lower (3500 ms) reaction-time limits, then the window dimensions were increased or decreased, respectively, by a factor of 1.1. This minimised differences in performance between individuals.

Participants then completed a second block of 80 trials in which the window size was fixed at the same size as it had been for that participant at the end of the first block. The same objects were presented in both blocks and the task was unchanged. Stimulus presentation was in a different, random order for each block and each participant. In the *active* group, participants actively controlled the movement of the window so, other than the fixed window size and trial order, the second block was identical to the first for this group. In the *passive-self* group, participants saw their own finger movements to a given object replayed from the first block. In the *passive-other* group, participants saw replays of the finger movements to a given object of participants from the *passive-self* group in the first block. Each participant in this group was paired with a different *passive-self* participant. The experimental package E-Prime 2.0 controlled the order of presentation of trials and recorded responses.

3 Results

3.1 *First block*

The task was the same for all groups in the first block, and thus any differences in performance would likely reflect stochastic variance rather than an effect of theoretical interest. Furthermore, since the aperture could vary every 5 trials, measures of performance over the whole block or for individual aperture sizes (for which the number of trials per participant varied widely—see figure 2) would not appropriately characterise performance.

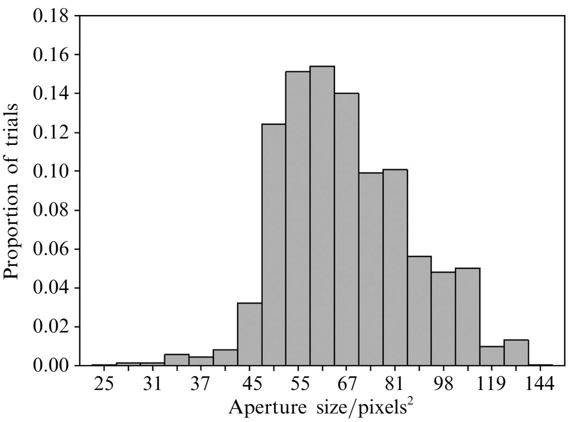

Figure 2. Proportion of total trials at each aperture size in the first block. Note that the *x*-axis is nonlinear since the dimensions of each successive aperture were 1.1 times greater than the next smallest aperture.

Nevertheless, the final values of the aperture are important, since they determined the size of the aperture in the second block. The modal final aperture size was 81 pixels^2. If the aperture size differed across groups then this may explain subsequent differences in performance observed in the second block. The distribution of aperture size was non-normal for the *passive-self* group (assessed using Shapiro-Wilk, $D_{15} = 0.83$, $p = 0.009$); as such, a nonparametric Kruskall–Wallis test, which does not require a normal distribution, was conducted using group (*active*, *passive-self*, and *passive-other*) as a between-participants factor and final aperture size as the dependent variable. Final aperture size did not significantly differ ($H_2 = 3.627$, $p = 0.2$) across the *active* (mean aperture size = 81 pixels^2, SD = 28), *passive-self* (64 pixels^2, SD = 18) and *passive-other* (81 pixels^2, SD = 31) groups.

Accuracy was similarly high for all three groups (90%, 92%, and 91% for the *active*, *passive-self*, and *passive-other* groups, respectively). Note that only speed, not accuracy, was used to vary aperture size. Varying aperture size in block 1 succeeded in maintaining most reaction times (RTs) within the required range of 3.5–6 s. The mean RT was 4638 ms, 4382 ms, and 4753 ms for the *active*, *passive-self*, and *passive-other* groups, respectively.

3.2 *Second block*

Since the effect of familiarity per se was not of theoretical interest and did not interact with group[(2)], data were collapsed across the familiar and unfamiliar conditions. Only RTs on correct trials were included in the analysis.

[(2)] A mixed ANOVA using familiarity as a within-participants factor and group as a between-participants factor found no interaction between familiarity and group for RTs ($F_{2,42} = 0.163$, $p = 0.9$) or errors ($F_{2,42} = 0.265$, $p = 0.8$).

The data were analysed with a one-way analysis of variance (ANOVA) with group as a between-participants factor. Shapiro – Wilk tests of normality indicated that the RT distributions of the *active* group ($D_{15} = 0.849$, $p = 0.02$) and *passive-other* group ($D_{15} = 0.811$, $p = 0.005$) significantly departed from normal: both exhibited significant skew to the right. The RTs were thus log-transformed to reduce this skew. Shapiro – Wilk tests on the log-transformed distributions demonstrated that this transformation was effective in reducing the violation of normality in these two groups (*active* group, $D_{15} = 0.914$, $p = 0.2$; *passive-other* group, $D_{15} = 0.888$, $p = 0.06$). Subsequent analyses were therefore performed on log RTs for all three groups.

There was a trend of group on speed of decision for RTs ($F_{2,42} = 3.008$, $p = 0.06$, $\omega = 0.43$) but not for errors ($F_{2,42} = 0.286$, $p = 0.8$)—see figure 3. We tested two specific hypotheses using planned contrasts. First, that participants passively viewing a moving aperture may outperform participants actively controlling the aperture. Second, that participants viewing replays of their own movements may perform better than those viewing replays of other participants' movements. The planned contrasts revealed that participants made the object-familiarity decision faster when they actively (mean $\log \mathrm{RT} = 3.47$; 2971 ms) moved the window as opposed to when they passively observed it (mean $\log \mathrm{RT} = 3.55$; 3517 ms), $t_{42} = -2.433$, $p = 0.01$, $r = 0.35$, and that there was no advantage to viewing replays of one's own movements (mean $\log \mathrm{RT} = 3.55$; 3517 ms) as opposed to somebody else's (mean $\log \mathrm{RT} = 3.56$; 3613 ms), $t_{42} = -0.313$, $p = 0.4$, $r = 0.05$.

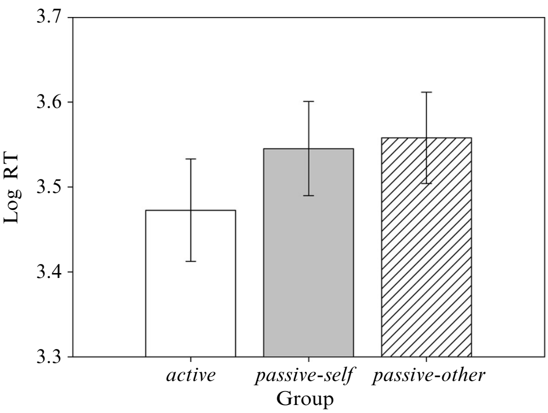

Figure 3. Log RTs in the second block as a function of group. Error bars are 95% confidence intervals.

3.3 *Movement profiles*

Our data can also be used to visualise the movements made during exploration of the object. To exemplify this, we produced movement maps to illustrate which areas of a given object were preferentially chosen for viewing. First, for every object image we aggregated all of the coordinates of the centre of the square aperture across each trial for every participant and created a 1024×768 matrix with each individual cell corresponding to a pixel. The value of each cell represented the number of times that the pixel was at the centre of the aperture. For each time that a particular location was recorded, a square of the model aperture size (81 pixels^2) was superimposed on that location to create a second 1024×768 matrix for each object image.[3] For example, if a particular location was recorded 16 times, 16 squares centred on that location were added to the matrix. This allowed us to count how many times each pixel was visible. The values of the cells in the resultant matrix were then normalised to the range 0 – 1, with 1 representing the maximum number of occasions on which any pixel was visible—see figure 4.

[3] These plots could also be made using the exact aperture size on a given trial; for illustrative purposes, we used the modal value.

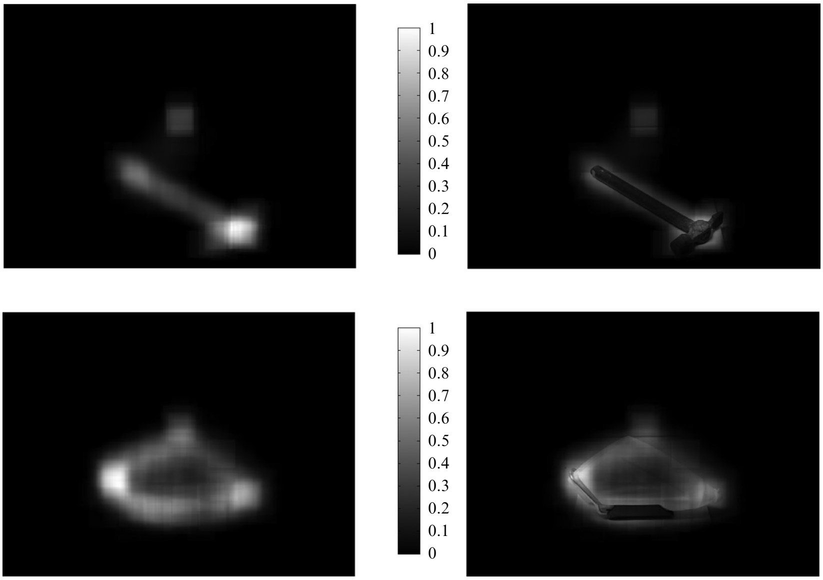

Figure 4. Movement maps aggregated across participants for the hammer (top) and unfamiliar object (bottom) shown in figure 1, for the maps only (left) and then for the maps overlaid on the original images of the objects (right). The lighter and more transparent the map, the more times that area was viewed. Note that the central fixation cross presented at the start of every trial resulted in a central square of activity in all images.

Cursory inspection of these maps suggested that participants tended to spend more time viewing extremities of objects rather than their centres, tracing the external contour where the aperture was not wide enough to span the viewed object. Note, however, that the stimuli were not selected to control for factors which may bias participants to adopt such a strategy.

4 Discussion

We examined recognition of objects under three different conditions of aperture viewing: active-control, passive viewing of replays of one's own movements, and passive viewing of replays of another participant's movements. Participants recognised the objects more quickly when actively controlling the aperture, and there was no advantage to passively viewing one's own movements as opposed to those of other participants. Our findings thus show the same advantage for active viewing of objects to those in previous visual studies (eg Harman et al 1999; James et al 2001), and agree with Króliczak et al's (2003) suggestion that active aperture viewing would be better than the passive viewing used in previous studies. However, our findings were different from previous results from the haptic recognition of raised-line drawings (D'Angiulli et al 1998; Magee and Kennedy 1980), which showed an advantage for passive over active exploration.

Hochberg (2007 [1968]) and Girgus et al (1980) suggested that participants would build up a 'schematic map' of a viewed stimulus: a set of expectancies of what would be seen at specific places in the image. Participants in the second block of our study had already seen each object once, and so had the opportunity to build a schematic map of each object. They may have used this map to aid their familiarity decisions in the second block. In particular, active control of the window may have been faster than passive viewing because it allowed participants to guide exploration towards more informative areas of the image.

Additionally, in the passive movement conditions participants could not accurately predict the extent, speed, and direction of the aperture's movements. This could, in turn, make it harder to compare the input to a stored memory of the objects presented in the first block. Thus, overall active movement may have provided more direct information about object shape and it may have allowed more direct testing of the spatial relationship between particular object parts and contours.

Participants in the *passive-other* condition saw the movements made by those in the *passive-self* condition during initial, active exploration. Both groups thus received largely the same perceptual information in the second block, with only their experience in the first block differing. There was no difference between these two conditions, suggesting that second block performance was not influenced by memory for the movements made in the first block and that people were not tuned to their own movement patterns. Alternatively, if participants largely used the same exploratory strategies and movements to explore particular objects in the first block, the input in both passive conditions would be so similar that no differences between them would be predicted.

Our results also suggest that there was no cost during aperture viewing of executing and planning movements, which Magee and Kennedy (1980) proposed to explain their finding of a passive advantage in haptic recognition of raised-line drawings. Richardson et al (1981) also suggested that there was a cost of planning and choosing the direction of movements. Given that our participants were recognising objects for a second time, any such burden was probably reduced, with participants using memory and other cues to guide their movements. Furthermore, our stimuli were relatively rich compared to the line drawings used by Magee and Kennedy (1980) and D'Angiulli et al (1998), and the raised-line paths used by Richardson et al (1981). Our objects contained surface detail and shading, and were photographed in a simple scene (see figure 1). With line drawings, most information is contained in the outline.

Nevertheless participants tended not to distribute their looking time uniformly across the objects, focussing instead on particularly distinctive areas (eg the head of the hammer —see figure 4). Furthermore, where objects were larger than could be fully visible within the aperture, participants tended to follow a closed-loop around the outside contour of the object, only briefly scanning the inside of that contour. This suggests a preference for following such contours when viewing is restricted, and is thus consistent with previous experiments showing similar patterns of exploration when the aperture is moveable (Króliczak et al 2003). Note, however, that this may be an accident of sampling: the objects and specific views selected may simply lend themselves to this kind of strategy.

Our study is the first to demonstrate that there is an advantage to object recognition of active control during aperture viewing. Previous studies used either passive viewing (eg Girgus et al 1980; Haber and Nathanson 1968; Rock 1981) or active viewing (Króliczak et al 2003) alone. This advantage is consistent with other findings of an active versus passive advantage in visual object recognition (Harman et al 1999; James et al 2001, 2002) in which vision was not restricted in the same way. As an extension to these findings, this is also the first experiment to show that this advantage holds for familiar as well as unfamiliar objects. Given the rich data the paradigm can yield, it may prove a useful tool in further exploring the reasons for this active advantage.

References

Anstis S M, Atkinson J, 1967 "Distortions in moving figures viewed through a stationary slit" *American Journal of Psychology* **80** 572–585

Craddock M, Lawson R, 2008 "Repetition priming and the haptic recognition of familiar and unfamiliar objects" *Perception & Psychophysics* **70** 1350–1365; doi:10.3758/PP.70.7.1350

D'Angiulli A, Kennedy J M, Heller M A, 1998 "Blind children recognizing tactile pictures respond like sighted children given guidance in exploration" *Scandinavian Journal of Psychology* **39** 187–190

Gibson J J, 1962 "Observations on active touch" *Psychological Review* **69** 477–491

Girgus J S, Gellman L H, Hochberg J, 1980 "The effect of spatial order on piecemeal shape recognition: A developmental study" *Perception & Psychophysics* **28** 133–138

Haber R N, Nathanson L S, 1968 "Post-retinal storage? Some further observations on Parks' camel as seen through the eye of a needle" *Perception & Psychophysics* **3** 349 – 355
Harman K L, Humphrey G K, Goodale M A, 1999 "Active manual control of object views facilitates visual recognition" *Current Biology* **9** 1315 – 1318
Hochberg J, 2007 [1968] "In the mind's eye", in *In the Mind's Eye: Julian Hochberg on the Perception of Pictures, Films, and the World* Eds M A Peterson, B Gillam, H A Sedgwick (Cary, NC: Oxford University Press)
Itti L, Koch C, 2000 "A saliency-based search mechanism for overt and covert shifts of attention" *Vision Research* **40** 1489 – 1506
James K H, Humphrey G K, Goodale M A, 2001 "Manipulating and recognizing virtual objects: Where the action is" *Canadian Journal of Experimental Psychology* **55** 113 – 122
James K H, Humphrey G K, Vilis T, Baddour R, Corrie B, Goodale M A, 2002 "Learning three-dimensional structure: A virtual reality study" *Behavior Research Methods, Instruments, & Computers* **34** 383 – 390
Klatzky R L, Lederman S J, Metzger V A, 1985 "Identifying objects by touch: an 'expert system'" *Perception & Psychophysics* **37** 299 – 302
Króliczak G, Goodale M A, Humphrey G K, 2003 "The effects of different aperture-viewing conditions on the recognition of novel objects" *Perception* **32** 1169 – 1179
Lawson R, Bracken S, 2011 "Haptic object recognition: How important are depth cues" *Perception* **40** 576 – 597
Lederman S J, Klatzky R L, 1987 "Hand movements: A window into haptic object recognition" *Cognitive Psychology* **19** 342 – 368, doi:10.1016/0010-0285(87)90008-9
Loomis J M, Klatzky R L, Lederman S J, 1991 "Similarity of tactual and visual picture recognition with limited field of view" *Perception* **29** 167 – 177
Magee L E, Kennedy J M, 1980 "Exploring pictures tactually" *Nature* **283** 287 – 288
Morgan M J, Findlay J M, Watt R J, 1982 "Aperture viewing: A review and synthesis" *Quarterly Journal of Experimental Psychology Section A* **34** 211 – 233
Parks T E, 1965 "Post-retinal visual storage" *American Journal of Psychology* **78** 145 – 147
Richardson B L, Wuillemin D B, MacKintosh G J, 1981 "Can passive touch be better than active touch? A comparison of active and passive tactile maze learning" *British Journal of Psychology* **72** 353 – 362
Rock I, 1981 "Anorthoscopic perception" *Scientific American* **244** 145 – 153
Symmons M A, Richardson B L, Wuillemin D B, 2004 "Active versus passive touch: Superiority depends more on the task than the mode", in *Touch, Blindness, and Neuroscience* Eds S Ballesteros, M Heller (Madrid: Universidad Nacional de Educación a Distancia) pp 179 – 185
Vrins S, de Wit T C J, Lier R van, 2009 "Bricks, butter, and slices of cucumber: Investigating semantic influences in amodal completion" *Perception* **38** 17 – 29

Appendix

Familiar objects

Bulldog clip	Key	Pliers	Stapler
Calculator	Knife	Plug	Tap
Cassette tape	Ladle	Razor	Tape measure
Cheese grater	Measuring jug	Salt cellar	Teapot
Comb	Mouse	Scissors	Tin opener
Corkscrew	Mug	Screwdriver	Toothbrush
Fork	Padlock	Shoe	Torch
Hammer	Paintbrush	Sieve	Whisk
Hole-punch	Peg	Spanner	Whistle
Jar	Pen	Spoon	Wooden spoon

ISSN 0301-0066 (print) ISSN 1468-4233 (electronic)

PERCEPTION

VOLUME 40 2011

www.perceptionweb.com