Temporal Factors and the Sharing of Cross-Modal Information

Andrew T.Woods, Sile O'Modhrain, and Fiona N.Newell

Department of Psychology, Trinity College Dublin, Ireland.
{Woodsat, Fiona.Newell} @tcd.ie
Media Lab Europe, Sugar House Lane, Bellevue, Dublin 8, Ireland.
Sile@media.mit.edu

Abstract. This paper hopes to further our understanding of cross-modal processing of simple stimuli. Cross-modal matching tasks were conducted where the two objects to be matched were presented to vision and touch at different times. The stimuli used were 'L-shaped' objects with varying lengths in the X and Y dimensions. Participants were shown a visual and a haptic object and were asked whether they were the 'same' or 'different'. In experiment one, the objects were presented in a serial order, with an inter-stimulus interval (ISI) of either 0, 15 or 30 seconds. Visual-haptic and haptic-visual temporal decay of sensitivity to object change was found to be the same and a two-dimensional change was easier to detect than one-dimensional changes. Experiment two found no performance difference between synchronous and immediate serial object presentation. Thus, a temporal window of optimum performance may exist with presentation outside of this subject to memorial decay.

1 Introduction

Vision and touch explore the world in very different ways, but their resultant representations can contain quite similar information. This paper intends to explore how temporal delays can affect the sharing of spatial object information, which is accessible to both modalities. A consideration is the way the visual and haptic modalities explore the world: as vision can extract information at a much faster rate than touch, the time allocated to each modality for gathering object information needs to be controlled to allow a similar level of accuracy to be achieved across the modalities (e.g. [1]).

When the presentation of the haptic and corresponding visual stimuli overlap in time, factors such as Modality Encoding Bias [2], rate of feature sampling (serial feature inspection for touch and parallel for vision, [3]), and the scope of the exploration of each modality (peripersonal space for touch, the horizon for vision) become important. As the size of the temporal disparity increases, with the presentation to the two modalities perhaps now not overlapping, other factors start to influence performance. Memorial decay factors would become increasingly influential, with perhaps the modality most recently presented to dominating the other modality. It may be the case that there is an optimum time for presentation; objects shown within this temporal window may not be affected by memorial decay [4].

2 Experiment 1

We tested observer sensitivity to spatial changes when two "L-shaped" objects were presented 0s, 15s or 30s apart by measuring accuracy. Reaction times (RT's) were also measured.

2.1 Method

Sixteen undergraduates from Trinity College Dublin participated in the experiment for research credits. The stimuli consisted of an identical haptic and visual set of 25 unfamiliar objects. All were 'L' shaped, differing from each other in 1cm increments along the lengths of their x-axis and y-axis extensions. 'L'-shaped objects were used as they are less prone to the creation of false percepts, such as haptic horizontal and vertical illusions [5]. The minimum length for both extensions was 2cm and maximum length being 6cm. Haptic stimuli were held in place in front of the participant, and were occluded from view by a custom-made monitor stand. Visual stimuli were displayed on a CRT monitor and were calibrated so they were identical in size to the haptic stimuli.

The experiment was of mixed-subject design. The within-subject variables were the duration of the inter-stimulus interval (*ISI*: 0, 15, 30 seconds), and *spatial* differences (x-axis, y-axis or x and y-axis differences). The between-subject variable was the *order* of modality presentation (touch-vision [TV], or vision-touch [VT]). A cross-modal, same-different, delayed match-to-sample paradigm was used, where participants had to state out loud whether they thought the stimuli were the "*same*" or "*different*" from each other (50% of the trails were "*same*" trials). For each trial, the participant had to first feel/see an object and then see/feel a second object (trials were always cross-modal). In order to make encoding equivalent across the modalities, visual stimuli were presented for 250ms and haptic stimuli for 3000ms. These timings were determined in a pilot study. A microphone recorded participant responses during the experiment.

2.2 Results and Discussion

Each participant's mean hit and false positive scores were converted to d', a psychophysical measure of sensitivity which takes into account participant response bias (mean values were used as 1.3% of the data was lost due to background noise). The mean d' values for each delay are plotted in Figure 1a. A Mixed-factorial ANOVA was conducted, using *ISI* and *order* as factors. A main effect of *delay* was found [$F(2,28)=7.515$, $p<0.005$]. The absence of an interaction effect [$F(2,28)=.327$, $p>.05$] suggests that the VT and TV trials' temporal decay of performance decreased at the same rate. A separate ANOVA was conducted on RT, revealing a main effect of *ISI* [$F(2,28)=8.304$, $p<0.005$] and *order* [$F(1,14)=20.329$, $p<0.001$), with no other effects evident. Thus, memory for the first object decays with time causing a decrease in performance and an increase in time to access the memory trace (this is in line with a similar primate study [6]). Performance decays at the same rate for VT and TV trials, perhaps suggesting they use similar underlying memorial mechanisms.

The mean correct responses for the levels of the *spatial* condition are plotted in figure 1b. A Mixed-factorial ANOVA was conducted, using *spatial* and *order* as the factors and Correct Response (CR) as the dependent variable. A main effect of *spatial* was found [F(2,28)=42.926, p<0.001]. No other effects were evident. Thus, two-dimensional changes were easier to detect than one-dimensional changes.

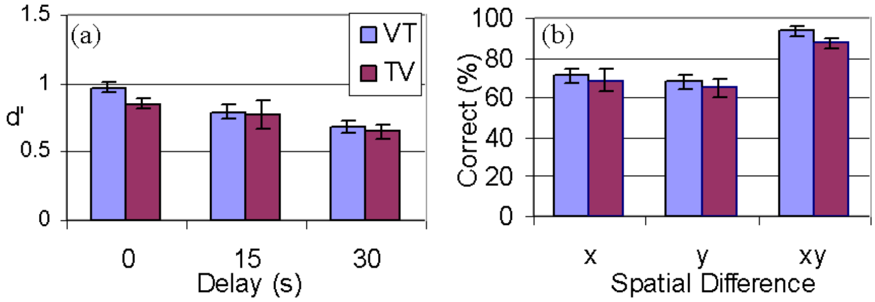

Fig. 1a and 1b, showing total percent correct across the types of spatial difference. 1b, showing D' values across the three different delays. Error bars in all the figures depict the standard errors of the groups.

3 Experiment 2

We tested the effects of synchronous presentation on performance and RT. A temporal window of optimum performance, which is not dependent on perceived temporal synchrony of object presentation, may be evident if serially presented trials achieved an equivalent level of performance to synchronous trials.

3.1 Method

Twenty-two undergraduates from Trinity College Dublin participated in the experiment for research credits. The stimuli and apparatus and general procedure were the same as in Experiment 1. The experiment was of a two-way within-subject design. The within-subject variables were the type of *presentation* (blocked trials of VT, TV or synchronously presented objects [SYNC]). A cross-modal, same-different, blocked, match-to-sample paradigm was used. Visual and haptic stimuli were both presented for 3000ms (ISI for VT and TV trials was 0.5s).

3.2 Results and Discussion

The mean d' values and RTs for SYNC, VT and TV presentations are plotted in Figure 2a and 2b (5.6% of the data was lost due to background noise). Repeated measures ANOVA's were conducted, with *presentation* as the dependent variable. No main effect were found for d' values across the levels [F(2,42)=1.554, p=.223]. For RT, a main effect of *presentation* was observed [F(2,42)=79.335, p<.001] and a posthoc Newman-Kuels analysis revealed that VT differed significantly from TV and SYNC (p<.001 for both), but that TV and SYNC did not statistically differ (p=.290). Thus, people performed equally well on stimuli which were presented at the same time, and those that were presented in close serial order. It appears that the effect of a disjointed perception of two objects appearing at slightly different times itself has no effect on matching performance.

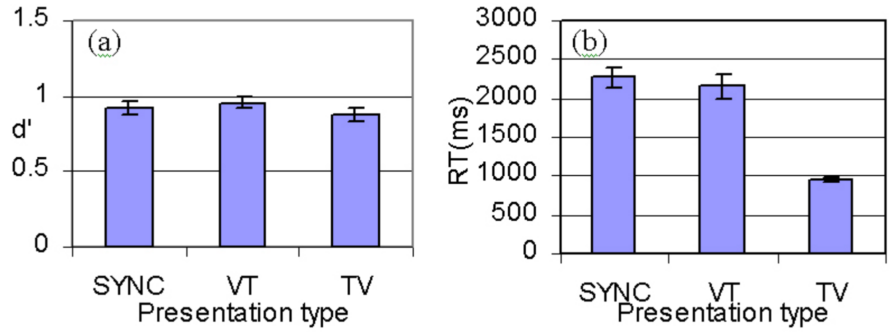

Fig. 2a and 2b. showing d' values for the presentation levels and 2b showing reaction time across the levels.

4 Overall conclusions

With increasing ISI's, observer performance will decline and take longer to match objects across modalities. This could be because the decaying memory trace of the first object would both be more error prone and would take longer to access [6]. The rate of decay was equivalent in VT and TV trials, suggesting that vision and touch use similar memorial systems to store information. A temporal window of optimum performance may exist for object matching. Performance was also found to decrease with a reduction in the number of dimensions the objects differed on.

References

1. Davidson, P.W., Abbott, S., Gershenfeld, J.:Influence of exploration time on haptic and visual matching of complex shape, Percept. Psychophys. 15 (1974) 539-543
2. Lederman S.J., Klatzky R.L.: Hand movements: A window into haptic object recognition, Cog. Psychol. 19 (1987) 342-368
3. Gibson J.J.: Observations on active touch, Psychol. Rev. 69 (1962) 477-491
4. Gilson, E.Q., Baddeley, A.D.: Tactile short-term memory, Quarterly J. of Exp. Psychol. 21, (1969). 180-184.

5. Heller, M.A. & Joyner, T.D.: Mechanisms in the haptic horizontal-vertical illusion: Evidence from sighted and blind subjects, Percept. Psychophys. 53 (1993) 422-428
6. Dimattia, V., Posley, K.A., Fuster, J.M.: Crossmodal short-term memory of haptic and visual information, *Neuropsychologia*. 28 (1990) 17-33