Neuroscience Letters 487 (2011) 17–21

Contents lists available at ScienceDirect

Neuroscience Letters

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

Inter-ocular and intra-ocular integration during prehension

Steve Hansen [a], Spencer Hayes [b], Simon J. Bennett [b,*]

[a] Brock University, CANADA
[b] Liverpool John Moores University, UK

ARTICLE INFO

Article history:
Received 17 February 2010
Received in revised form 24 August 2010
Accepted 22 September 2010

Keywords:
Prehension
Visual control
Binocular
Monocular
Alternating

ABSTRACT

This study examined the inter-ocular (alternating monocular samples) and intra-ocular (monocular or binocular samples) integration during a prehensile task with a range of occlusion intervals (0–75 ms). In the first experiment, participants were uncertain regarding the impending visual condition, as well as target size and location. In the second experiment, a pre-cue on target location was provided. Data from both experiments indicated that participants modified their movement kinematics when provided with alternating monocular samples, irrespective of whether or not there was an occlusion interval. Similar adaptations were found in conditions requiring intra-ocular integration but only following the introduction of an occlusion interval. These findings are consistent with participants having a general intolerance for alternating monocular samples and as a consequence using a more cautious reach and grasp strategy.

Briefly presented visual samples can be integrated over time when the intra-ocular occlusion period is shorter than the intrinsic persistence of the visual samples [5]. In motor tasks demanding high precision (i.e., manual aiming, one-handed catching), the persistence of binocular samples (20 ms duration) enables performance to be maintained with intra-ocular occlusion periods of no longer than approximately 40–80 ms [4,7]. On the other hand, monocular samples (20 ms duration) seem to have a shorter persistence of approximately 20 ms [2,14]. The implication is that the control of tasks involving high precision is not only dependent on the duration of the intra-ocular occlusion interval, but also whether the visual input is provided to one or both eyes.

The finding of a difference in the persistence of binocular and monocular vision that facilitates performance of precision tasks has led to recent attempts to determine the duration over which the monocular input can be integrated between the eyes. In an experiment [14] based on the method developed by [8], participants made more one-handed ball catches when provided with 20 ms or 80 ms alternating monocular samples than in a condition of continuous monocular vision. It was suggested that individuals were capable of gaining useful information by integrating alternating monocular samples presented without an inter-ocular occlusion as long as the time between alternating samples to the same eye did not exceed 80 ms. Contradictory evidence was obtained with a variation of this methodology that included an inter-ocular occlusion between the alternating monocular samples [3,2]. In those experiments, the proportion of balls caught in monocular and alternating monocular conditions did not differ regardless of the occlusion interval and was consistently worse compared to corresponding conditions of binocular vision.

To better determine the temporal integration limits of binocular vision, a recent study investigated the integration of alternating monocular samples during prehension [18]. Providing participants with continuous binocular vision resulted in smaller average grip apertures than a continuous monocular vision condition, as well as conditions in which alternating monocular samples were separated by an inter-ocular occlusion as short as 14 ms. This result was replicated in a second experiment where visual feedback of the hand was occluded for the initial 80% of the movement. The authors suggested that the larger grip aperture in the alternating monocular vision conditions, which would have been "largely programmed before the reach begins" (p. 96), could not be accounted for by participants having difficulties integrating highly dissimilar retinal images as the hand approached the target. Moreover, it was concluded that the participants adopted a cautious reach and grasp strategy as a consequence of having *no tolerance* for the integration of alternating monocular samples to provide a binocular percept.

In the above study, alternating monocular conditions had inter-ocular occlusion that ranged from 14–58 ms. It remains unclear, therefore, if participants could have integrated alternate monocular samples presented consecutively (i.e., without an inter-ocular occlusion) [14]. Furthermore, to date there has been no detailed report on measures of movement kinematics as the hand is transported from the home position to the target [12,13]. For instance, it is unknown whether participants increase movement time and change the proportion of time spent in the accelerative or decelerative phases of the movement following the introduction of an

* Corresponding author at: Brain and Behaviour Research Group, Liverpool John Moores University, Byrom Street, Liverpool L3 3AF, UK.
E-mail address: s.j.bennett@ljmu.ac.uk (S.J. Bennett).

0304-3940/$ – see front matter. Crown Copyright © 2010 Published by Elsevier Ireland Ltd. All rights reserved.
doi:10.1016/j.neulet.2010.09.065

inter-ocular occlusion. This omission is important because binocular information from retinal disparities has been shown to be particularly important for the latter on-line control of prehensile movement [13].

Nine males (right hand, right eye dominant) from the host University provided informed consent prior to participating in this experiment. All procedures were conducted in accordance with the local ethical guidelines and the 1964 declaration of Helsinki. Participants were required to perform a prehensile task that involved reaching out to "grasp" 2D square targets located in their mid-saggital plane. Specifically, they were instructed to place the index finger and thumb on the edges of the targets in the same way they would when grasping a real 3D square target. A visual stimulus generator (ViSaGe) with proprietary software (CRS Toolbox) operating in MATLAB (Mathworks Inc.) presented the targets on a 21-in. computer monitor (refresh rate of 160 Hz). The monitor was mounted horizontally in a wooden frame and had a clear Perspex overlay mounted 5 mm above the screen surface. White target squares were presented against a black background and contained a thin black cross (2 mm thick) that bisected their width. Either a small (24 mm × 24 mm) or a large (36 mm × 36 mm) square was presented at a near (285 mm) or far (385 mm) distance. The home position was located approximately 200 mm from the participant.

Participants wore a pair of PLATO liquid crystal goggles throughout the protocol. The state of the liquid crystal lenses was manipulated to provide binocular, monocular or alternating monocular vision during the grasping movements. In the binocular condition, both lenses were transparent or opaque at the same time, whereas in the monocular conditions only the left lens was cycled between transparent and opaque states. In the alternating monocular conditions, the left and right lenses were alternately switched between transparent and opaque states such that vision was only available to one eye at a time. When vision was continuous there was no occlusion interval (0 ms) between 25 ms samples presented to both eyes (binocular condition), the left eye alone (monocular condition), or alternately between the right and left eyes (alternating monocular). For all other intermittent vision conditions, the state of the liquid crystal goggles was cycled such that participants were provided with a 25 ms sample (both eyes, left eye, alternate left or right eye) followed by a 12.5, 25, 50 or 75 ms occlusion interval: note that taking account of minimal delays inherent from switching states of the liquid crystal lenses (i.e., TranslucentTechnologies, Inc. technical report), it can be estimated that the opaque state was approximately 3 ms shorter than the driving signal.

Participants completed 300 pseudo-randomly ordered trials (15 vision conditions, 2 target location, 2 target size, 5 repeats), which were separated into five blocks of 60. Each block comprised 15 trials to each of the two target locations and two target sizes. A trial began with the participant placing their finger and thumb together at the home position. The goggles were then switched opaque for 500 ms after which a target square appeared and simultaneously the goggles cycled between opaque and transparent states. Participants were asked to perform the prehensile task as quickly and as accurately as possible.

Movement of markers attached to the distal end of the index finger, thumb, and radial-carpal joint was recorded at 200 Hz for the duration of the trial with a Qualysis ProReflex optoelectronic system; system accuracy has been measured at 0.5 mm [15]. Post experimentation, the resulting three-dimensional position data were filtered using a second order dual pass Butterworth filter with a low-pass cut-off frequency of 8 Hz [11]. The filtered position data were differentiated to acquire velocity data. From these data, we extracted reaction time, time after peak velocity, maximum grip aperture and movement time [11].

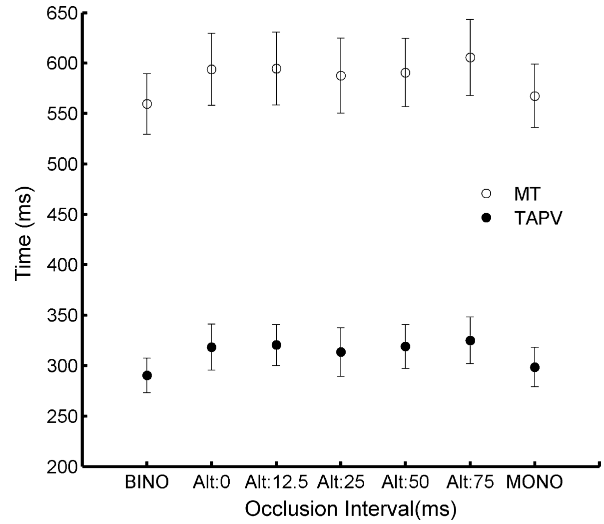

Fig. 1. Movement time (MT) and time after peak velocity (TAPV) in Experiment 1 as a function of vision condition (BINO: continuous binocular, Alt: alternating, 0, 12.5, 25, 50, 75, MONO: continuous monocular). Standard error of the mean indicated.

Inter-ocular integration was examined using separate one-way repeated measures ANOVA that compared the alternating monocular vision conditions (0, 12.5, 25, 50, 75 ms occlusion) to the continuous binocular and monocular vision conditions; see [14,18]. Intra-ocular integration was examined with separate 2-Vision Condition (binocular, monocular) by 5-Occlusion Interval (0, 12.5, 25, 50, 75 ms) ANOVA with repeated measures on both factors. Significant main effects and interactions were decomposed using Fisher LSD ($P < 0.05$). The different levels of target size (small, large) and location (near, far) were included in the experimental design in order to minimise advance planning. However, these factors did not interact with vision condition and hence were collapsed [see also 18].

Inter-ocular integration. There were no main effects for reaction time, $F(6, 48) = 0.70$, indicating that the amount of time spent planning the response was unaffected by vision condition and/or occlusion interval (grand mean = 256 ms). For maximum grip aperture, the effect of vision condition approached conventional levels of significance, $F(6, 48) = 2.10$, $P < 0.07$. Observation of the group means indicated that compared to continuous alternating vision there was a small increase in maximum grip aperture when the occlusion interval was longer than 12.5 ms (0 ms = 58.6 mm; 12.5 ms = 59.1 mm; 25 ms = 59.5 mm; 50 ms = 59.1 mm; 75 ms = 59.1 mm). Movement time, $F(6, 48) = 5.38$, $P < 0.05$, and the time after peak velocity, $F(6, 48) = 3.66$, $P < 0.05$, were significantly longer in all the alternating monocular conditions than in the continuous binocular or monocular vision condition (Fig. 1)

Intra-ocular integration. There were no main effects for reaction time. However, compared to continuous binocular and monocular vision conditions, participants exhibited a significant increase in movement time, $F(4, 32) = 5.27$, $P < 0.05$, and time after peak velocity, $F(4, 32) = 4.90$, $P < 0.05$, when there was a 12.5 ms occlusion interval (Fig. 2). This difference was maintained across all occlusion intervals but there was not always a further significant increase. In addition, there was a significant interaction for maximum grip aperture, $F(4, 32) = 3.57$, $P < 0.05$. The introduction of an intra-ocular occlusion interval in the monocular vision condition resulted in a small but significant increase in maximum grip aperture (0 ms = 58.1 mm; 12.5 ms = 59.3 mm; 25 ms = 59.0 mm; 50 ms = 59.4 mm; 75 ms = 59.1 mm). For the comparison to continuous binocular vision, maximum grip aperture