

EFFECTS OF FAST ADAPTATION WITH COMPLEX MOTION

Marcelo Maniglia, Andrea Pavan, Gianluca Campana, & Clara Casco.
Department of General Psychology, University of Padua, Italy

Abstract

Striate and extrastriate neurons present short-term synaptic depression and facilitation in response to brief-transient stimulations. Recent psychophysical studies have shown some empirical relationships between these short-term forms of neural plasticity and of psychophysical behavior. It has been shown that depending on the adaptation duration it is possible to induce two opposite perceptual outcomes: rapid visual motion priming (rVMP) (adapting for tens of ms), and rapid motion aftereffect (rMAE) (adapting for hundreds of ms). In the present study we stimulated MT and MST neurons via the presentation of contracting and expanding circular gratings in order to assess whether rapid effects exist at these higher levels of motion processing. Results revealed strong rMAEs, perceptual sensitization (PS), which is a long lasting facilitation but not rVMP. Our results are considered to reflect the competition between coexistent forms of short- and long-term synaptic depression and facilitation implemented at different visual cortical circuitries.

Transient stimulations are able to elicit rapid and opposite forms of neural plasticity; either short-term depression (Boudreau & Ferster, 2005) or short-term facilitation (Castro-Alamancos & Connors, 1996), that can coexist and compete in many cortical circuitries (Hempel et al., 2000). Recent psychophysical studies have described some possible relationships between these short-term forms of neural plasticity and patterns of psychophysical behavior. For example, using translational motion, brief exposures to directional motion can bias the perceived motion direction of a subsequently presented ambiguous (i.e., flickering) test pattern (Kanai & Verstraten, 2005; Pavan, et al., 2009). Depending on the duration of the adaptation stimulus and the adaptation-test blank interval (inter-stimulus interval - ISI), the perceived direction of an ambiguous test pattern can be biased towards the opposite direction (motion aftereffect – MAE), or towards the same direction (visual motion priming – VMP) to that of the adaptation pattern. In particular, previous studies (Kanai & Verstraten, 2005; Pavan et al., 2009) have shown that using brief adaptation durations (80 or 160 ms) and ISIs (40 or 120 ms), generated a rapid form of visual motion priming (rVMP); conversely, increasing the adaptation duration (320 or 640 ms) generated a rapid form of motion aftereffect (rMAE). However, it has been shown that using ISIs longer than 2 seconds, the perceived motion direction of the test pattern was biased towards the motion direction of the adaptation pattern (Perceptual Sensitization - PS; Kanai & Verstraten, 2005; Pavan et al., 2009). In this study we behaviourally assessed whether rMAE, rVMP and PS exist using complex radial motion (i.e., contracting and expanding patterns, known to selectively tap high-level of motion processing) and whether they exhibit the same or different temporal course to those observed in previous studies. The rationale was that using radial motion we elicit activity primarily at the level of the MT complex (Orban et al., 1992). Furthermore, in order to test the role of attentional components in these effects, we compared directional vs. ambiguous adaptations to optic flow. It is possible that high-level motion detectors, known to be implicated in the perceptual stabilization of the perceived direction of ambiguous moving stimuli (William et al., 2003), could be involved in the generation of rapid forms of adaptation, pointing to even

higher loci of processing for these effects with complex motion (LIP or MST). Finally, we assessed the temporal window within which these effects occur.

Experiment 1: brief adaptation to directional motion

In Experiment 1a we assessed the existence of rVMP, rMAE and PS using contracting and expanding concentric gratings. In addition, we aimed to investigate whether such rapid effects, if any, exhibit the same or different temporal courses to those reported in previous studies.

Method

Stimuli and Procedure

Stimuli (Figure 1) consisted of concentric circular gratings. For the adapting stimulus, the circular grating (1 c/deg) drifted either inward (contracting motion) or outward (expanding motion) at 4.16 Hz. To obtain directional stimuli, the phase of the gratings was shifted by ± 60 deg every 40 ms. The test stimulus consisted of a counterphase flicker made up of two superimposed circular gratings and drifting in opposite directions. The temporal and spatial frequencies of the two superimposed gratings were equal to that of the adapting pattern. The velocity of the test components was equal to that of the adaptation pattern (4.16 deg/s) across all the adaptation durations. The contrast of the stimuli was kept constant at 0.96 (Michelson contrast).

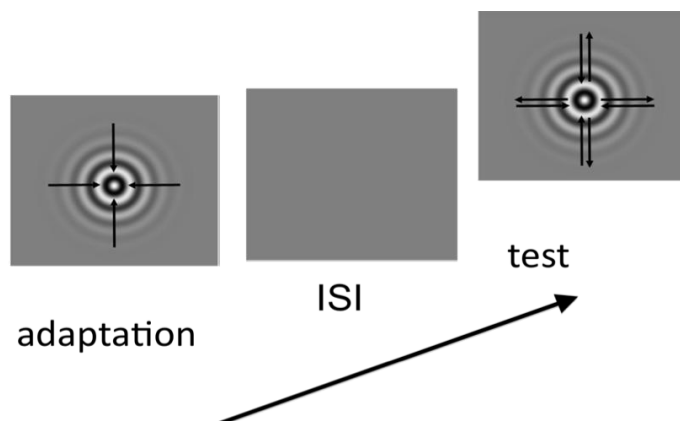


Figure 1: example of stimuli configuration for Experiment 1

Four adaptation durations were used: 80, 160, 320, and 640 ms. After a variable ISI (40 ms, 120 ms, 480 ms, 1 s and 2 s), a directionally ambiguous test pattern was presented for 320 ms. Subjects were asked to judge whether the test stimulus was moving in the same direction or opposite to the adaptation pattern.

Results and discussion

Results are shown in figure 2a. Data Points above 0.5 indicate priming effect, whereas those below under 0.5 indicate MAE effect. rVMP was not found. This finding is in contrast with the data obtained for translational motion in the previous works (Kanai & Verstraten, 2005; Pavan et al., 2009). However, a brief adaptation period of 80 ms and progressively increasing the ISI biased the perceived direction of the test pattern towards the same direction to that of the adapting stimulus resulting in a PS effect. On the other hand, longer adaptation durations (i.e., 160, 320 and 640 ms) biased the perceived direction of the

ambiguous test pattern towards the opposite direction to that of the adaptation pattern, resulting in rMAEs. (see Figure 2a).

Experiment 1b: brief adaptation to directional motion – long intervals

The purpose of the experiment 1b was to better investigate the timescale of the rMAEs and the PS effect found in the previous experiment.

Method

Stimuli were the same as those used in Experiment 1a. After a variable ISI (4, 6, and 8 s) an ambiguous test pattern was presented for 320 ms. Subjects had always to judge whether the test stimulus was moving in the same direction or opposite to the adaptation pattern.

Results and discussion

Figure 2b shows the results obtained in Experiment 1b. It seems that at a high-level of motion analysis brief exposures to directional motion are able to induce not only suppression but also facilitation that gradually arises and is maintained for long ISIs. The results concerning longer adaptation durations suggest that the PS effect could be masked by the simultaneous presence of rMAE. The results of Experiments 1a and 1b show that both rMAEs and PS effects are induced by optic flow components but they showed different timescales with respect to those reported in previous works (Kanai & Verstraten, 2005; Pavan et al., 2009). Moreover, there was a complete absence of rVMP. These results suggest that rMAEs and PS effects, though not rVMP, can take place at high-level of motion analysis and seem to depend on a neural plasticity based on different timescales to those observed in lower-levels visual cortical circuitries.

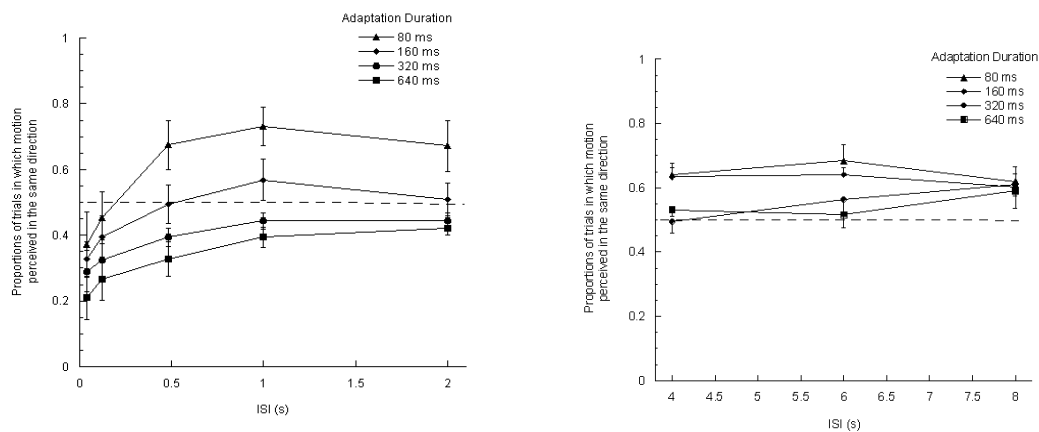


Figure 2a: Experiment 1. For each adaptation duration we plotted the proportions of trials in which the ambiguous test pattern was perceived to drift in the same direction to that of the adaptation pattern, as a function of the duration of the ISI. Figure 2b: Results for Experiment 1b

Experiment 2a: brief adaptation to ambiguous motion

In the last two experiments we adapted to directionally ambiguous patterns and test with ambiguous motion as well. If the activity of high-level motion detectors induces a perceptual stabilization of directionally ambiguous moving stimuli, then an ambiguous motion step should be perceived as directional and therefore suitable to induce adaptation. If this hypothesis is true, one would expect similar results to that obtained in Experiments 1.

Method

Stimuli and Procedure

Adaptation and test stimuli were directionally ambiguous, and consisted of a counterphase flicker made up of two superimposed circular gratings drifting in opposite direction (Figure 3). Four adaptation durations were used: 80, 160, 320, and 640 ms. After a variable ISI (40 ms, 120 ms, 480 ms, 1 s and 2 s), a test pattern was presented for 320 ms. Subjects judged whether the test stimulus was moving in the same direction or opposite to the adaptation pattern.

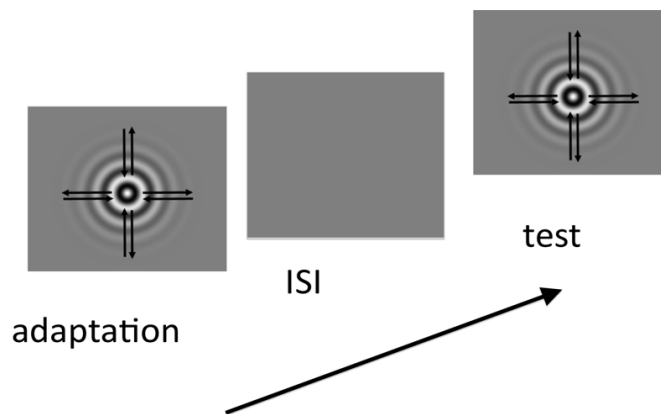


Figure 3: example of stimuli configuration for Experiment 2

Results and discussion

Figure 4a shows the results obtained in Experiment 2a. Adaptation to ambiguous motion induced only positive biases throughout the ISIs and across almost all the adaptation durations employed. The PS effects gradually develop with increasing the ISI, showing only a weak decline with the longer ISIs. These results could reflect the presence of a stabilization process for ambiguous displays, that is, initially the percept switches from one percept to the other (e.g., from contraction to expansion or vice versa), then after some exposure the pattern is perceived to drift in a unique direction (stabilization) (Leopold et al., 2002). It might be possible that for longer ambiguous adaptation durations more time is necessary for the percept to become stable, and this stabilization might occur during the ISI.

Experiment 2b: brief adaptation to ambiguous motion – long intervals

The purpose of the Experiment 2b was to better investigate the temporal course of the PS effects found in Experiment 2a.

Method

Adapting and test stimuli were the same to that used in Experiment 2a. Subjects had to judge whether the test stimulus was moving in the same direction or opposite to the adaptation pattern.

Results and discussion

Figure 4b shows the results obtained in Experiment 2b. Adapting to ambiguous motion the PS effects are not maintained across longer ISIs.

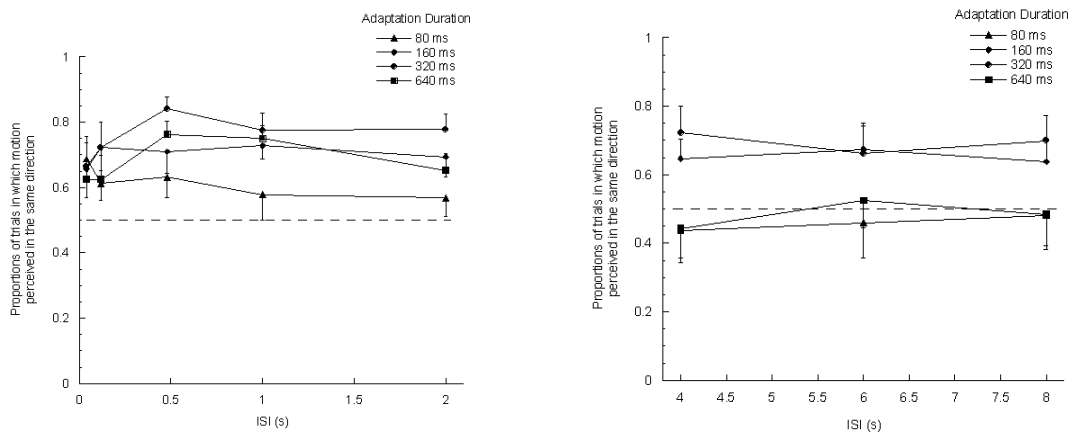


Figure 4a: results obtained in Experiment 2a. Figure 4b: results obtained in Experiment 2b

General Discussion

The results obtained with radial motion present relevant differences with respect to the findings of previous studies with simple translational motion (see Kanai & Verstraten, 2005; Pavan et al., 2009), indicating the presence of at least partially different underlying neural mechanisms and/or temporal dynamics of rMAE, rVMP and PS with complex motion patterns. Generally, using optic flow components, we obtained exclusively rMAEs and PS effects. Since Experiment 1a did not reveal any rVMP, we argue that rVMP might depend on motion detectors present at a low level of motion analysis (e.g., V1, V2/V3), and might be confined to simple translational motion.

One hypothesis for the lack of rVMP is that 80 ms are sufficient to adapt the MT neurons that selectively respond to radial moving patterns, but they are not sufficient to neurons of early visual cortices such as V1. It might be possible that different cortical areas express short-term depression and facilitation with different magnitude, frequency dependence, timescales and exhibit different interactions. The longer was the adaptation duration, the greater was the rMAE and longer was the recovery time: this might reflect a recovering process from short-term adaptation. Priebe, Churchland and Lisberger (2002), for example,

showed that 64 ms of stimulus presentation was sufficient to adapt MT neurons; this reflects the temporal dynamic of the rMAE we found when using 80 ms adaptation and 40 ms of ISI. The PS arise progressively increasing the ISI up to 1 s and is stronger for shorter adaptation durations. For longer adaptation durations, there seems to be a stronger rMAE that interferes with the deployment of a long-lasting form of facilitation(PS). Increasing the ISI duration we observed: (i) the recovery from short-term adaptation and, (ii) the progressive development of a long-lasting form of facilitation (PS). Hempel et al. (2000) showed a similar dynamic: their results pointed out also the presence of a slower form of enhancement of synaptic transmission occurring on the timescale of seconds to tens of seconds.

In the last series of Experiments we adapted to ambiguous motion. Since it has been shown that the activity of MST and LIP neurons are able to determine and constrain the motion direction of bistable stimuli, we were interested to assess whether the stabilization of ambiguous motion present in the first motion interval occurs and if it was able to induce short-term suppression (i.e., adaptation) or facilitation. Moreover, we were interested to assess the existence and, if any, the role of the long-lasting form of PS. Williams et al. (2003) have shown that the responses of many direction-selective neurons of MST and LIP areas were predictive of the animal's perceived direction of perceptually bistable apparent motion. Experimental evidences show that deployment of attention is necessary to perceive directional motion in bistable displays (Cavanagh, 1992). At the neuronal level, however, attentional modulation is generally weaker in MT than in MST or LIP (Treue & Maunsell, 1999). Thus for bistable apparent motion MT neurons might only provide a balanced, non-directional representation of the stimulus. Our findings could reflect these dynamics. In our last series of Experiments we found only the presence of PS effects, thus only unambiguous motion is able to induce adaptation (Williams et al., 2003).

To conclude, our results show that complex motion stimuli eliciting specifically the activity of higher level motion areas (i.e., MT and MST) are not able to produce rapid forms of visual motion priming (rVMP), but do produce rapid forms of motion aftereffect (rMAE) and slower forms of motion priming (PS).

Acknowledgements

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