Motion-based colour integration along S-cone modulation

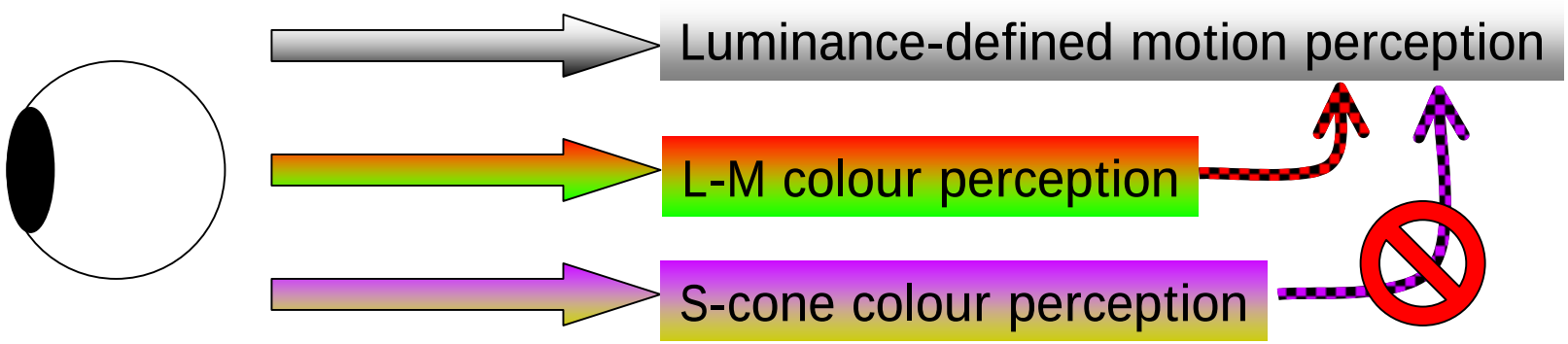
Junji Watanabe*, Ichiro Kuriki, Shin'ya Nishida

NTT Corporation, Japan
* also University of Tokyo, Japan

junji@star.t.u-tokyo.ac.jp

Introduction (1)

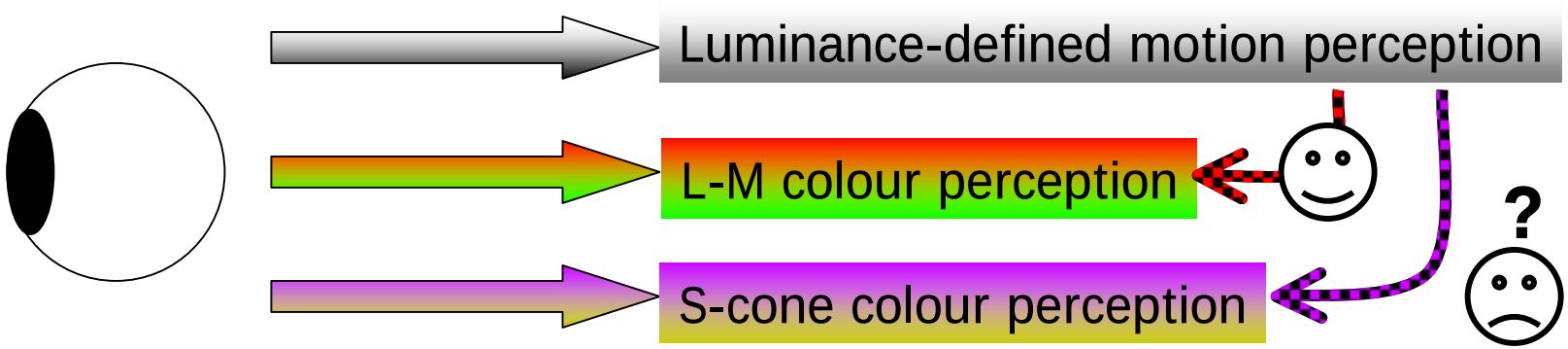
Human visual system separately analyses colour and motion ???



It is generally accepted that colour perception is relatively independent of visual motion processing[2].
Recent studies, however, have revealed that L-M chromatic modulations (parvocellular pathway) could significantly affect luminance-defined motion perception (magnocellular pathway)[3]. On the other hand, similar effects were not found for S-cone chromatic modulations, for which the third, koniocellular, pathway[4] is suggested to be responsible.

Introduction (2)

Motion-induced colour integration can occur
in S-cone chromatic modulation ???



Recently, we found “motion-induced colour integration”. This phenomenon demonstrates a direct modulation of colour perception by luminance-defined motion[5]. Specifically we have shown red-green colour perception can be modulated by motion perception. Here, we demonstrate that the chromatic processing in S-cone modulations also interacts with motion processing in motion-induced colour integration.

Motion-induced Colour Integration (1)

Motion-induced colour mixture

When a bar moves whilst alternating its colour between red and green, yellow (a mixture of red and green) is perceived. This indicates that two colours presented at different locations on the retina, but belonging to the same object, are mixed according to the motion path of the object.

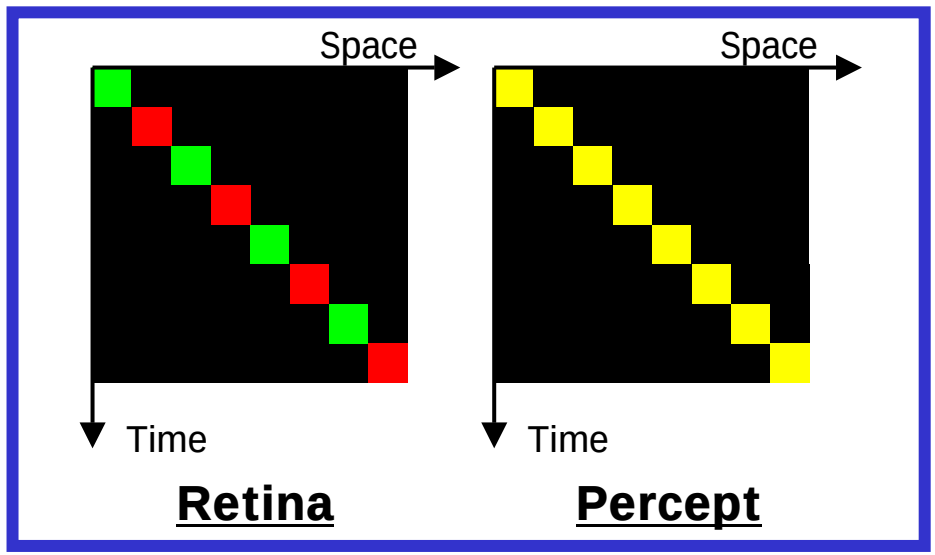
Time sequence of a color alternating bar

Physical color and movement

Expectation from the retinal image and its persistence

Actual Percept

Space-time view of a color alternating bar

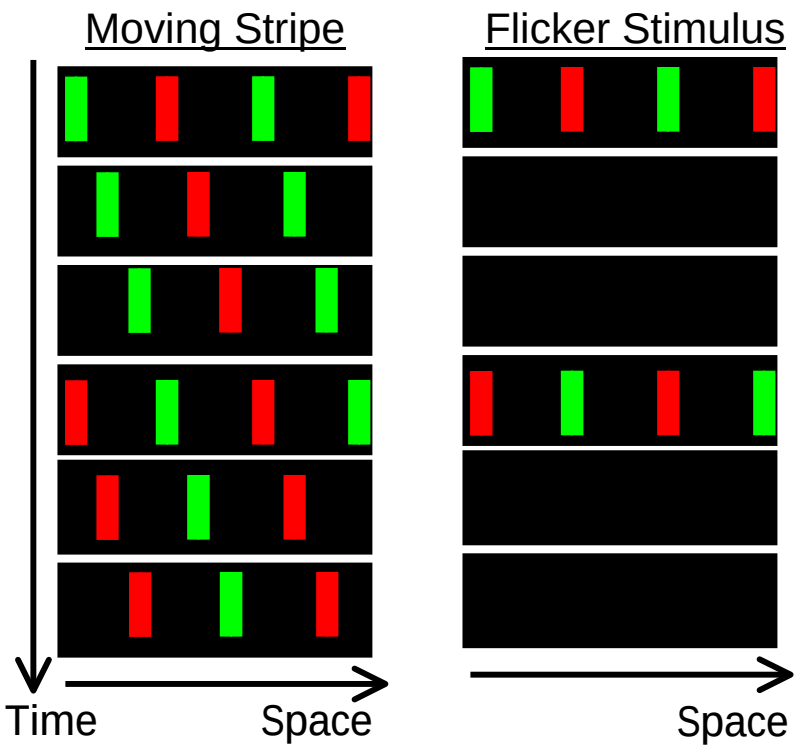


Motion-induced Colour Integration (2)

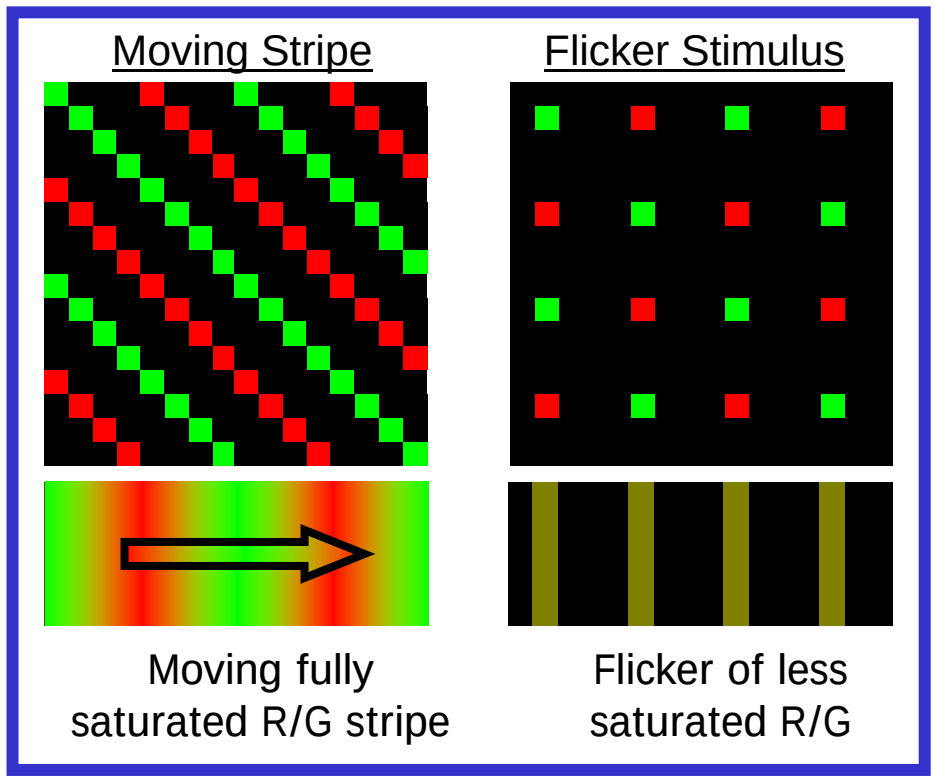
Motion-induced colour segregation

When a constant red/green stripe moves across the screen, perception of motion and colour is largely accurate, however when the same moving stripe flickers at the rate shown in the left diagram, static yellowish bars are perceived. This effect can be also ascribed to the direction-selective integration of colour information.

Time sequence of moving stripe and flicker



Space-time view of moving stripe and flicker



Question

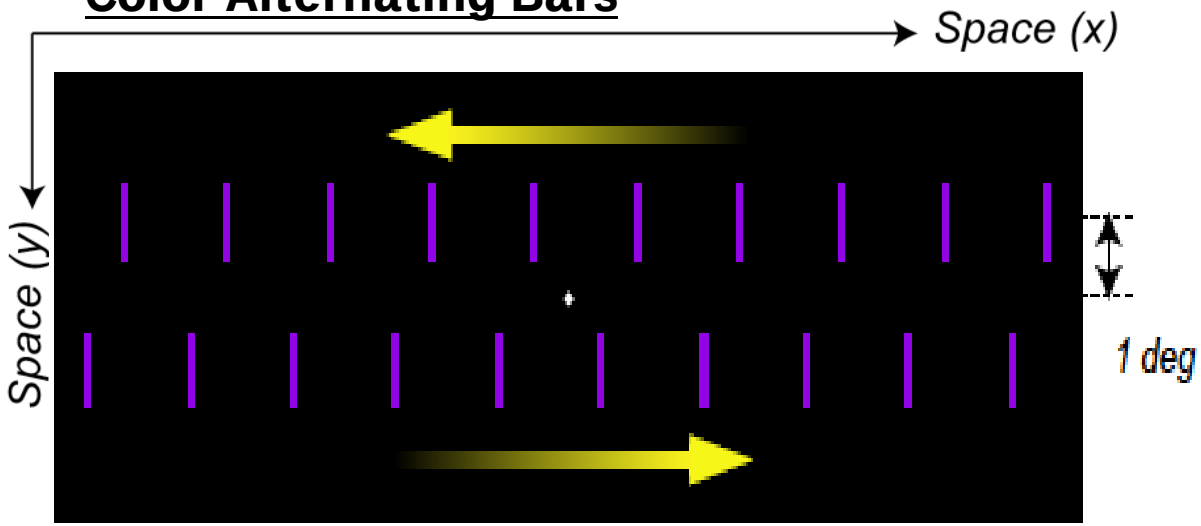
There are two primary axes in color space to which colour selective cells in LGN respond best
"difference between L- and M-cone responses (LM axis)",
"difference between S-cone response and the sum of L- and M-cone responses (S axis)"

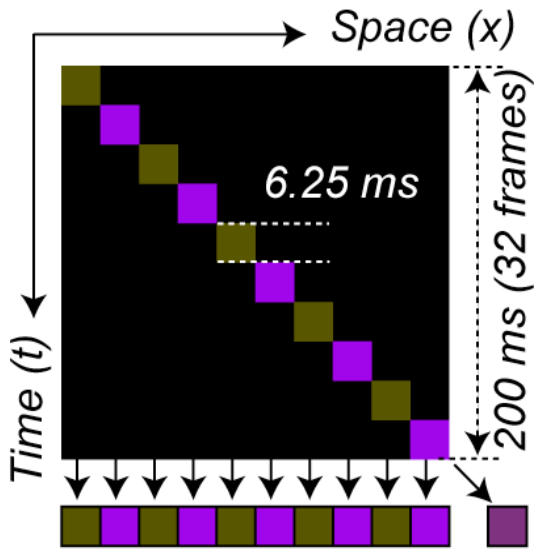
In our previous reports, colors were modulated only between red and green along the LM axis.

To see the generality of colour–motion interaction with regard to colour modulation direction, we replicated the experiments using colors along the S axis.

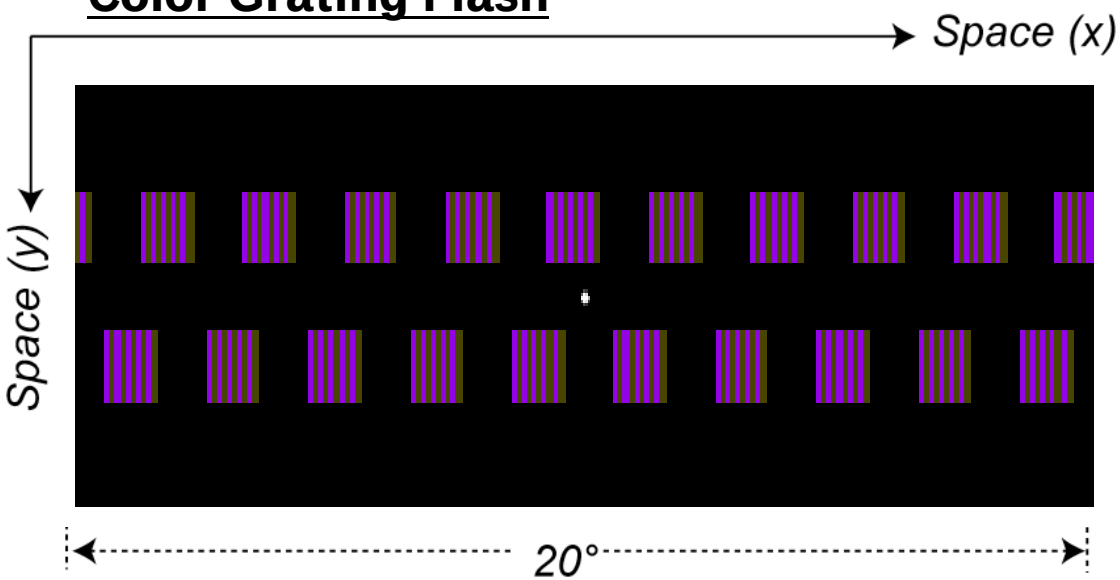
Stimulus (1) motion-induced colour mixture

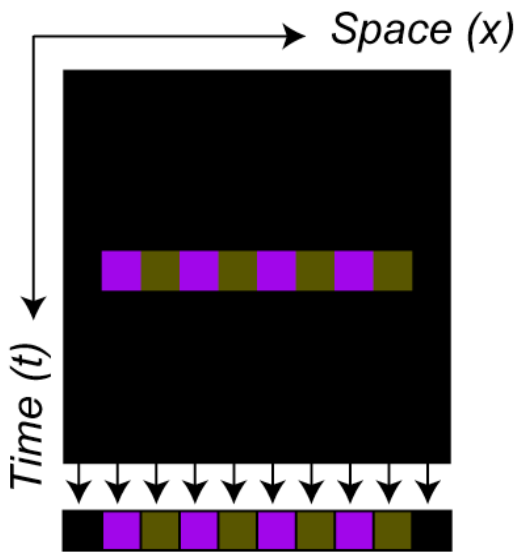
Color Alternating Bars



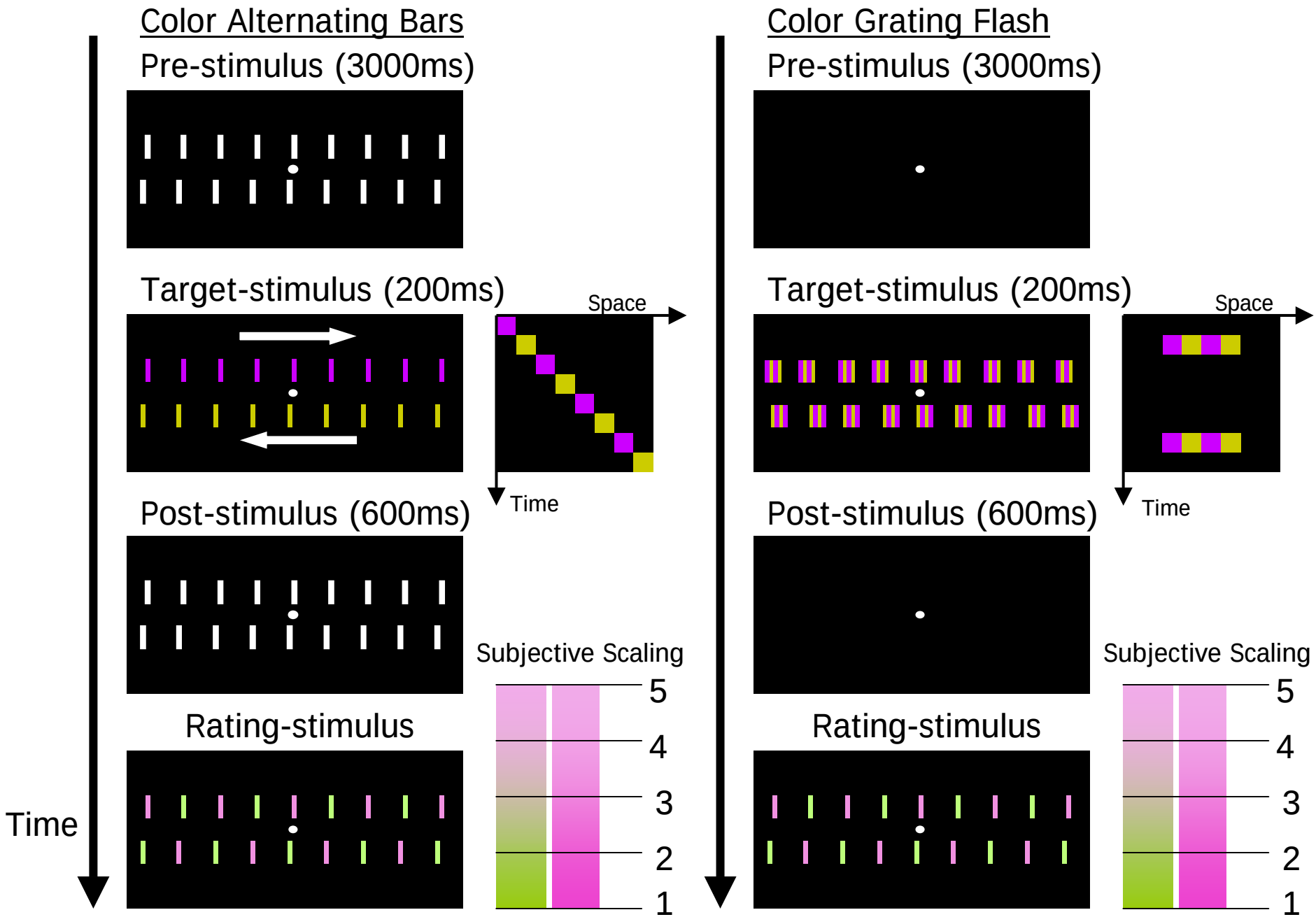


Color Grating Flash





Procedure (1) motion-induced colour mixture



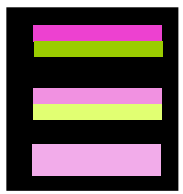
Parameter (1) motion-induced colour mixture

Parameters

Bar Width (BW) (5 steps)

3.0, 4.5, 6.0, 9.0, 12.0 min

Stimulus Color (3 steps)



1: No physical mixture

3: Partial physical mixture

5: Perfect physical mixture

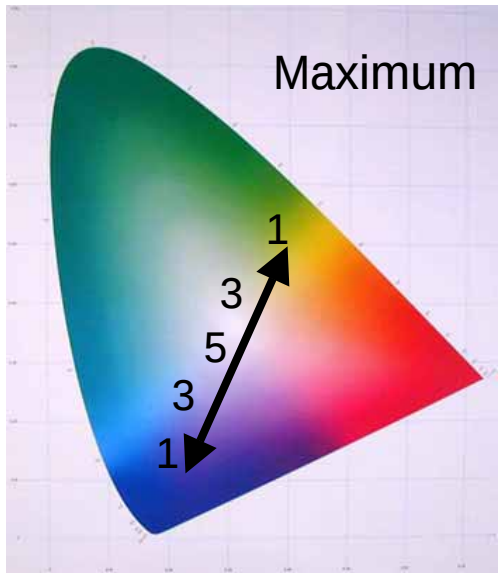
Presentation Style

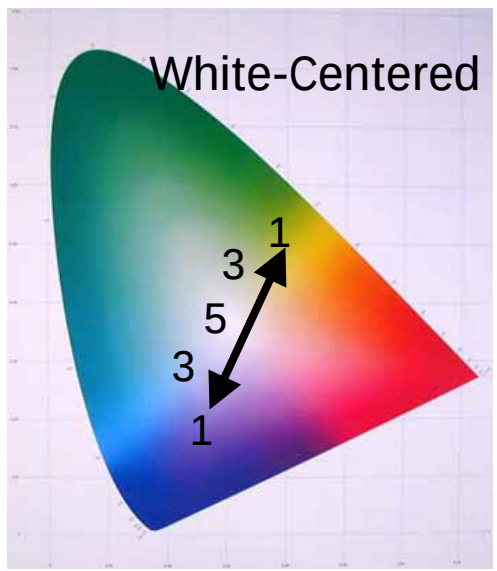
Color alternating bars

Color grating flash

We used Smith-Pokorny[1] cone fundamentals to calculate cone responses.

Colour axis (2 types)

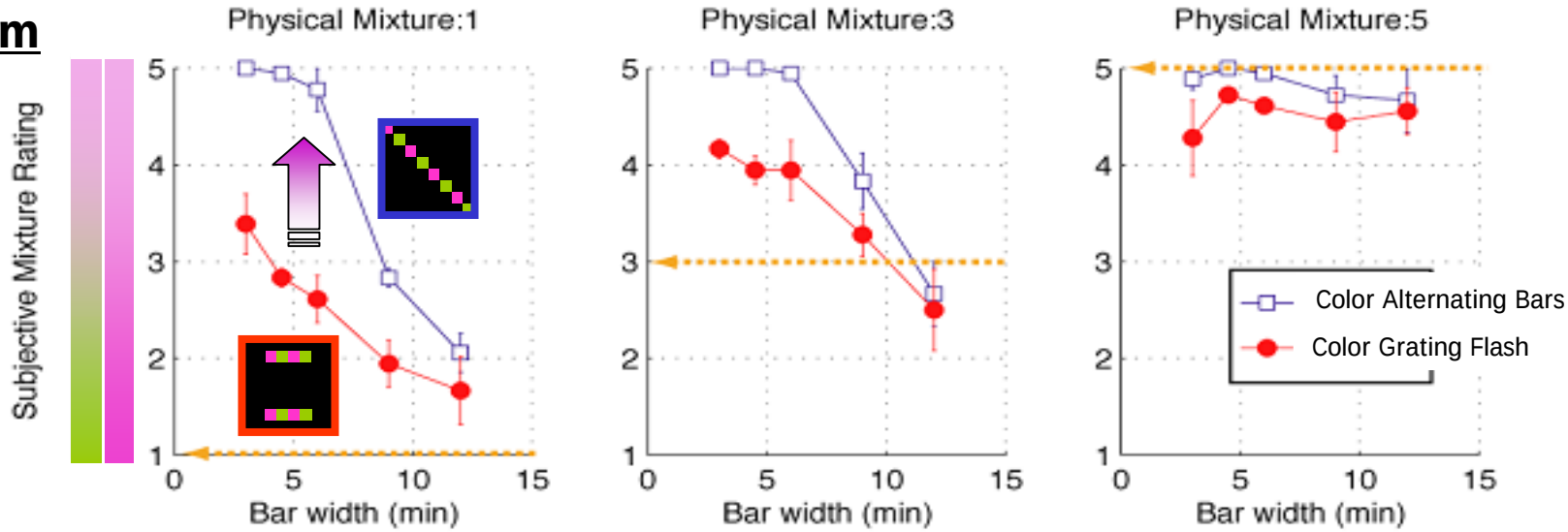




Result (1) motion-induced colour mixture

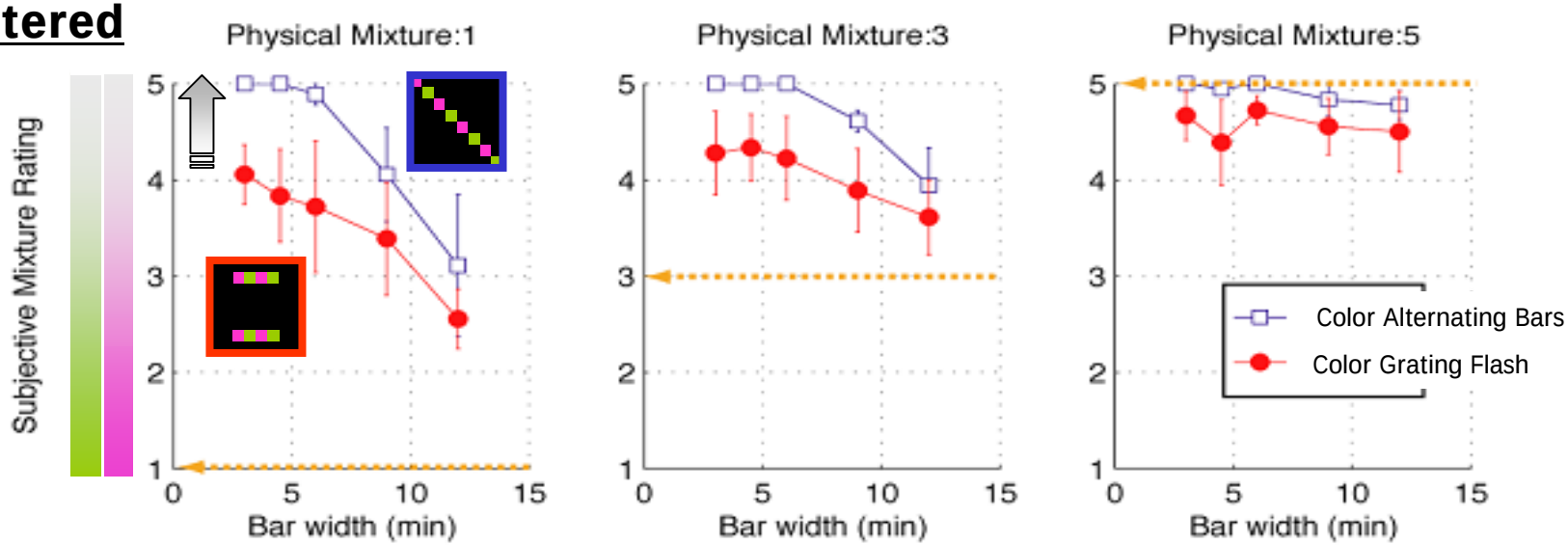
Maximum

N=3



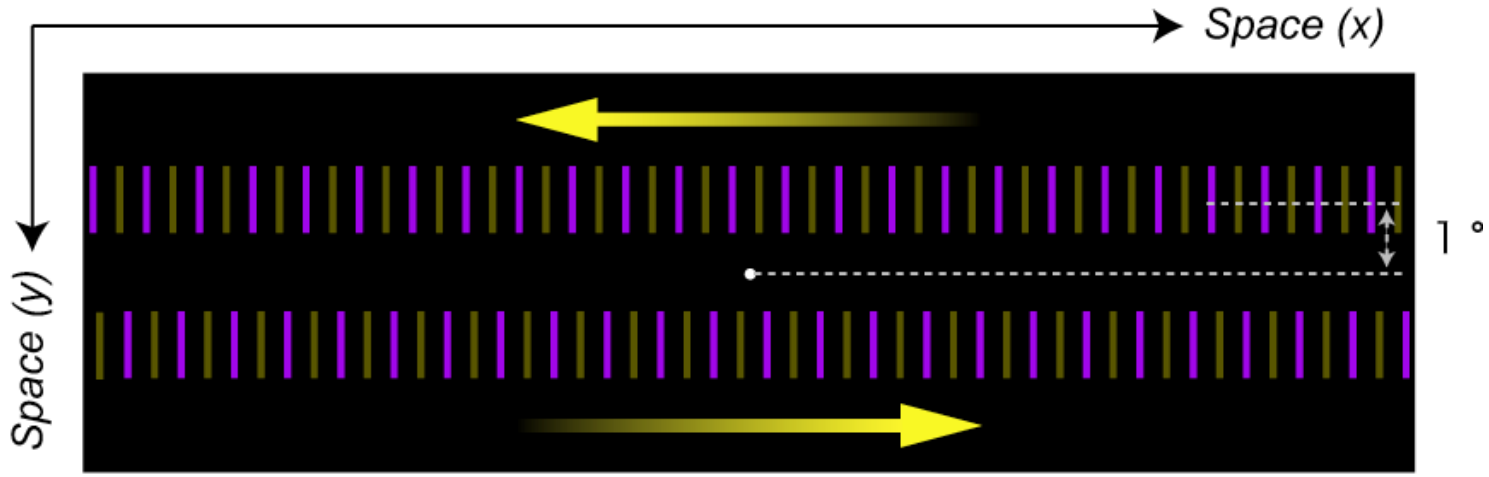
White-Centered

N=3

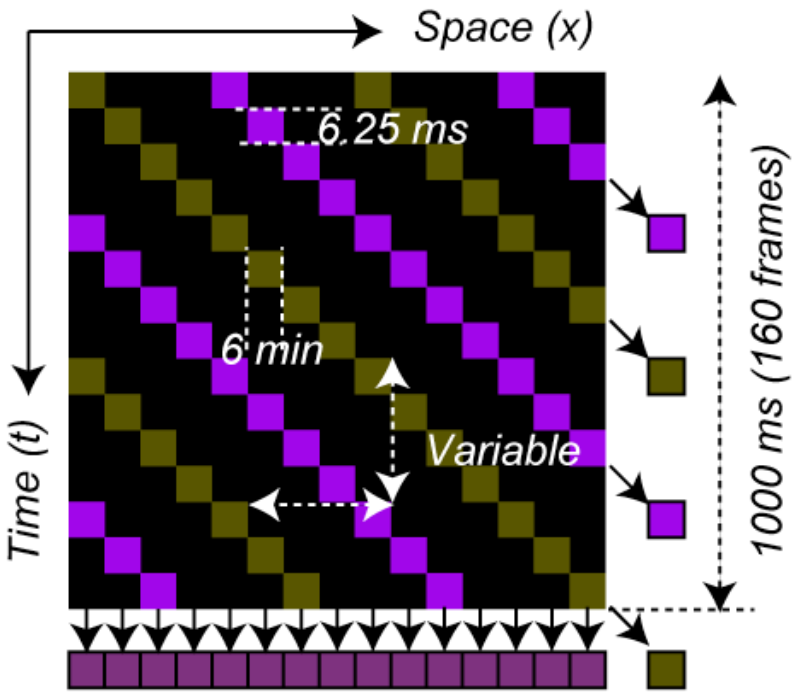


Stronger color mixture occurs in **Color Alternating Bars** than in **Color Grating Flash**.

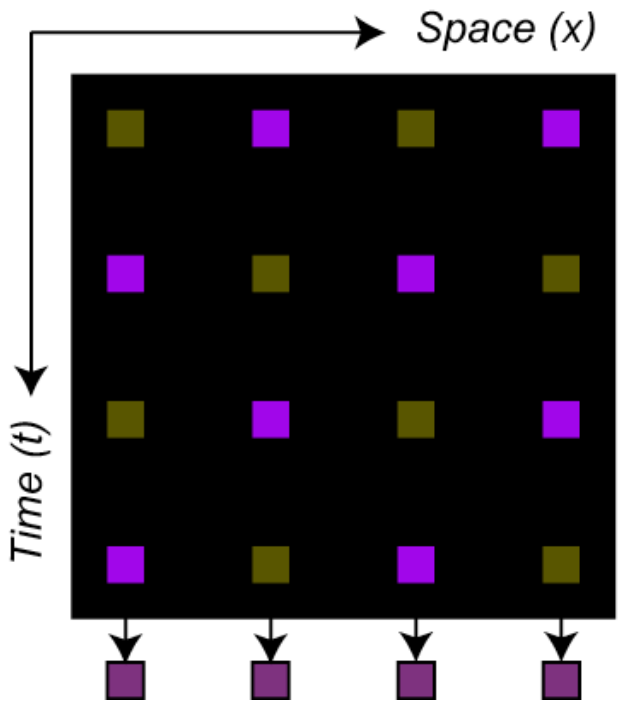
Stimulus (2) motion-induced colour segregation



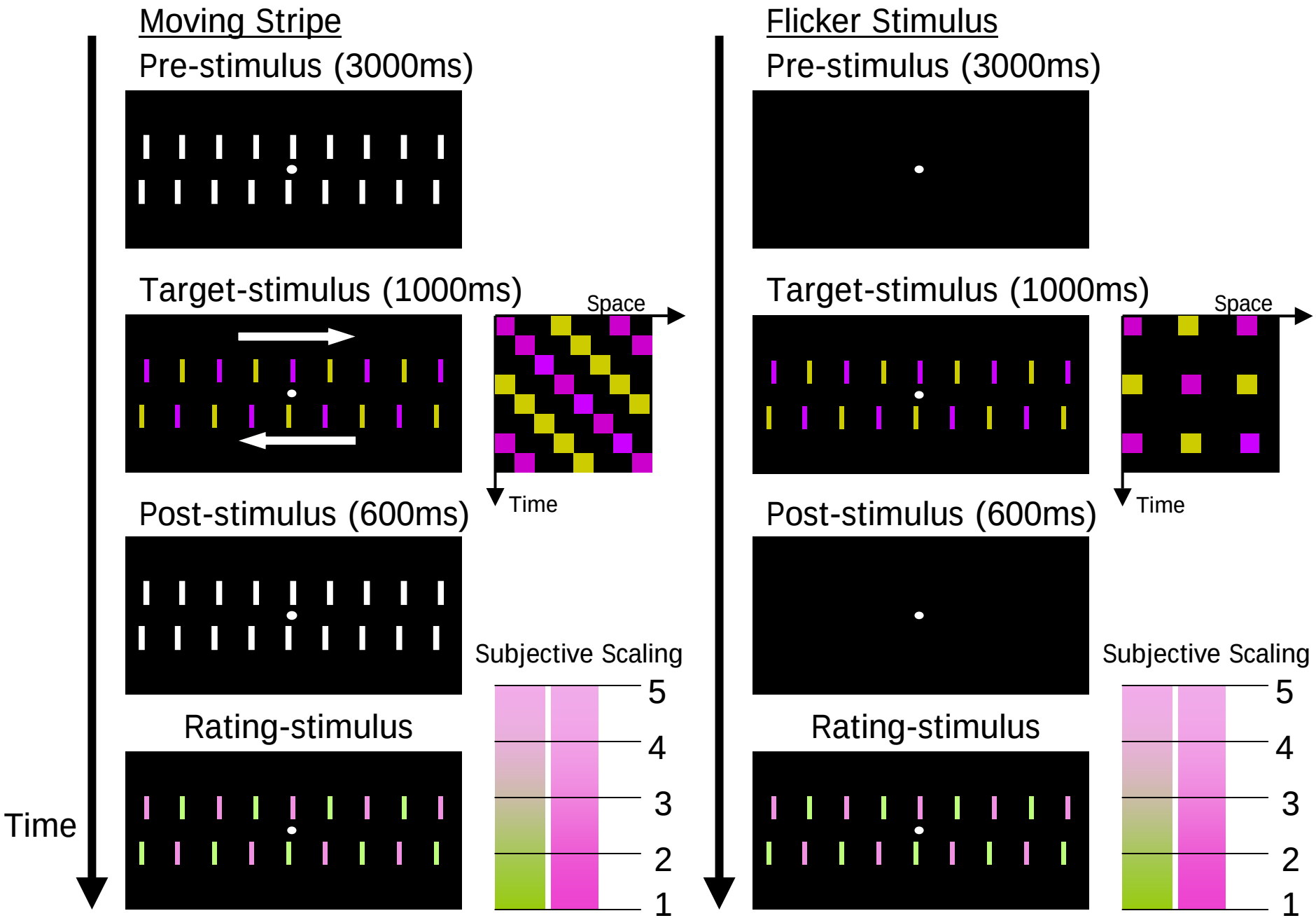
Moving Stripe



Flicker Stimulus



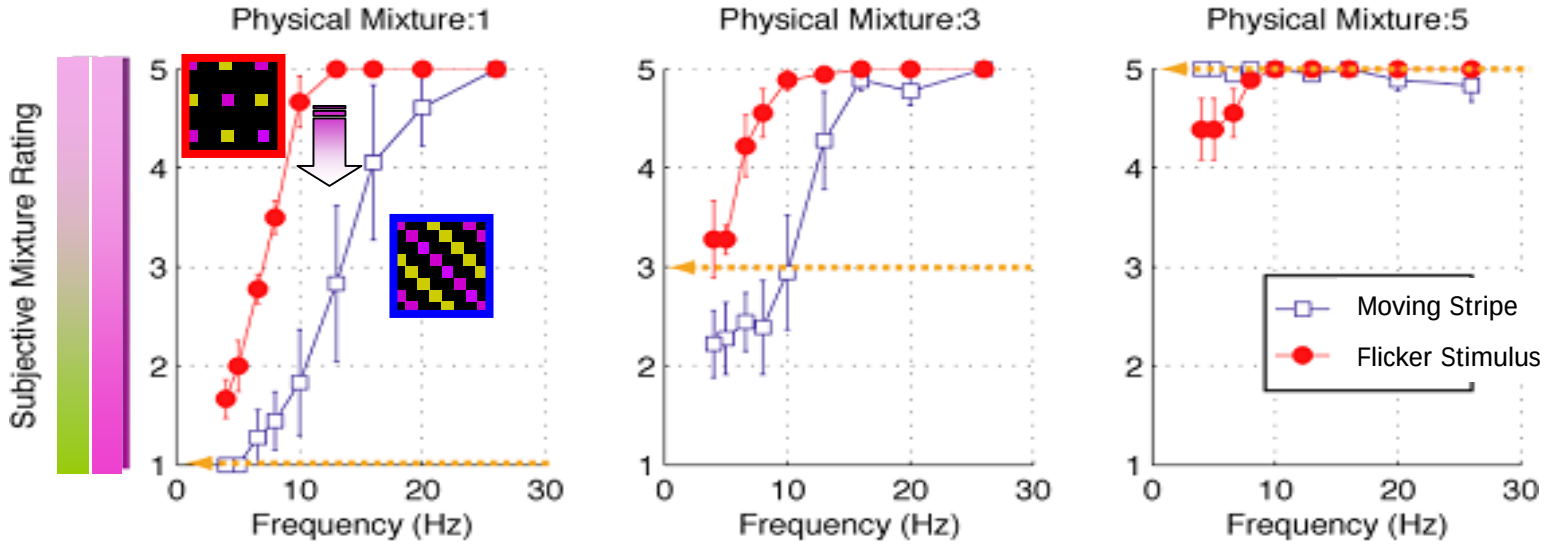
Procedure (2) motion-induced colour segregation



Result (2) motion-induced colour segregation

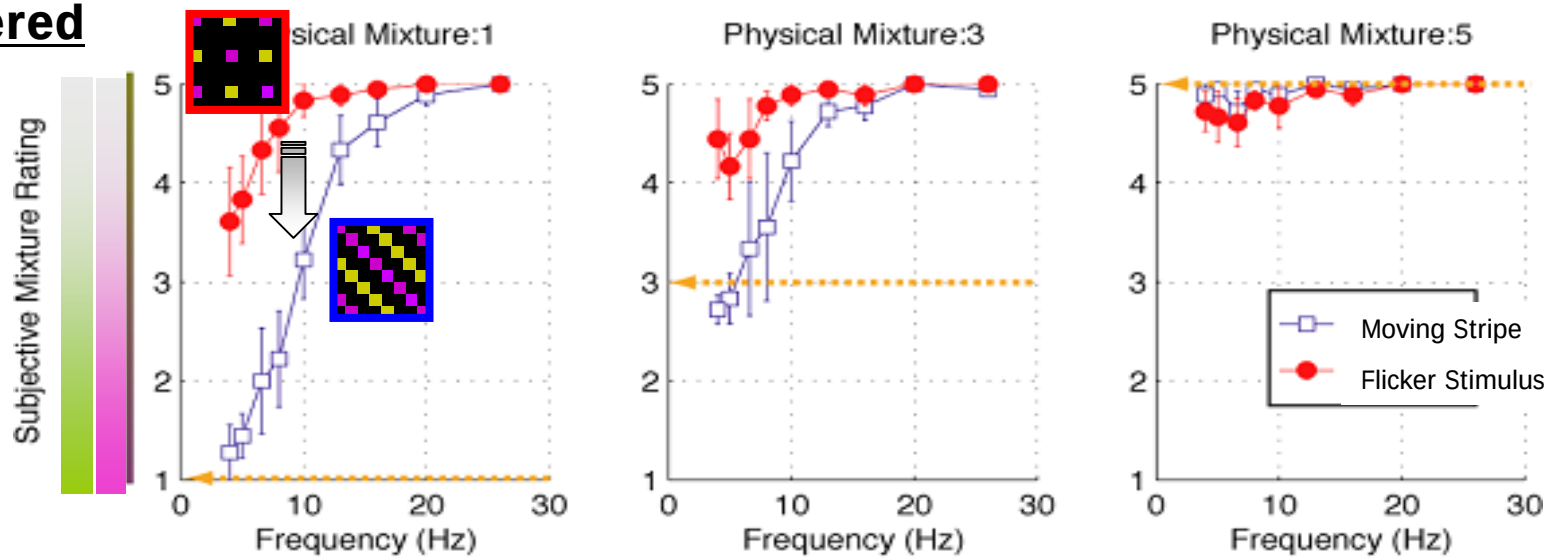
Maximum

N=3



White-Centered

N=3



Stronger color segregation occurs in **Moving Stripe** than in **Flicker Stimulus**.

Discussion & Conclusion

- Motion-induced colour integration (mixture & segregation) was also observed for colours modulated along the S-cone axis. This demonstrates that

  "chromatic processing in S-cone modulation can be influenced by motion processing"

  "motion processing facilitates veridical colour perception of moving objects regardless of the direction of color modulation".

- The detection of luminance motion is masked by chromatic flickers along L-M axis but not by those along the S axis (Takeuchi et al., 2003). This finding suggests the existence of an early pre-cortical colour-motion interaction. In contrast, chromatic non-selectivity of the current phenomena suggests the existence of a late colour-motion interaction involving cortical color mechanisms.

Related studies

- *[1] Cone response & Colour space*

  Smith & Pokorny, 1975; MacLeod & Boynton, 1979; Derrington et al., 1984

- *[2] Separate processing of motion and colour information*

  Zeki, 1978; Ungerleider & Mishkin,1982; Shipp & Zeki, 1985;
  DeYoe & van Essen,1985; Livingstone & Hubel, 1988

- *[3] Interaction of motion perception by colour*

  Cavanagh & Favreau, 1985; Krauskopf & Farell, 1990; Stoner et al., 1990;
  Cavanagh & Anstis, 1991; Kooi & De Valois, 1992; Stromeyer et al., 1995;
  Lu et al., 1999; Takeuchi et al. 2003; Dobkins & Albright, 2004

- *[4] S-cone axis & Koniocellular layer in LGN*

  Hendry & Reid, 2000; Xu et al. 2001

- *[5] Motion – induced colour integration & Interaction of colour perception by motion*

  Watanabe et al. ECVP2004,
  Cicerone et al., 1995; Nijihawan, 1997; Werner, 2004

Comments & Reprint request