# Stimuli and Apparatus

## Prism Adaptation (PA)

[Tutoriel Adaptation prismatique (Prs Y. Rosseti et G. Rode) - YouTube](https://www.youtube.com/watch?v=5KUSH43HvuM)

Prism adaptation consists in asking the participants to make ballistic pointing movements with their right arm toward a target. The pointing error induced by the leftward (LPA) optic shift triggers adaptation processes that realign the visual and proprioceptive sensory coordinates. The rightward remapping of space (termed “after-effect”) induced by LPA is observable when the prism glasses are removed and the participant asked to point toward a visual target without feedback, or asked to indicate their straight ahead with the eyes closed. To be successful, the PA procedure must respect multiple constraints, involving multiple parameters:

* **Number of target:** it usually varies between 3 (Rode et al., 2015) and 9 (Michel & Cruz, 2015). Most of the time this number ranges between 3 and 4.
* **Presentation of target:** The targets (eg, white dots) can be stuck on a black cardboard (Rode et al., 2015) or displayed by mean of a tactile screen. For example, in the experiment of Striemer et al. (2016), the participants must press a button in the starting position to trigger the target presentation on the tactile screen. After the pointing movement, they brought back their hand on the button to trigger the presentation of the next target.
* **Order of pointing:** the target of interest can be signalled verbally by the experimenter, in a random sequence. The experimenter can make reference to a direction (“left”, “right”; Herlihey et al., 2012) or a number (1,2,3,4; Ronga et al., 2018).
* **Pace of pointing:** this parameter is linked to the previous one. In the experiment of Striemer et al. (2016) the pace was self-monitored. At variance, Herlihey et al. (2012) used a metronome to normalize the timing of pointing (1 trial = 2 sec).
* **Number of pointing:** this parameter would be crucial to produce the “true” adaptation component, this latter considered as an ultra-slow adaptation process (McIntosh et al., 2019; Prablanc et al., 2020). McIntosh et al. (2019) showed that the magnitude of the after-effects on the line bisection and landmark tasks was modulated by the length of the pointing procedure. After-effects were larger in the experiments where the participants pointed during more than 10 min (short exposure), in comparison to those where the participants pointed during less than 10 min (long exposure). Nevertheless, time may act as a proxy for the number of pointing movements, which indicates that the pacing of pointing is also important. Because short exposure is usually associated to 200 pointing, and long exposure associated to 300 pointing, McIntosh et al. (2019) recommended a minimum of 250 pointing. Nevertheless, some experiments have used LPA with short exposure (7-10 min, 150 pointing) and obtained substantial after-effects on the proprioceptive straight ahead (PSA) and the landmark task (Schintu et al., 2014, 2017). At the extreme opposite, some studies have applied exposure of 20 min (Colent et al., 2000; Michel & Cruz, 2015), without considering the number of pointing movements.
* **Measurement of pointing error:** The team of Lyon uses two electrodes: one tethered on the centre of the black cardboard (aligned with the participant’s body midline), and one tethered on the index of the participant. When the index touches the table, a device registers the tension between the two electrodes. Then the position of the finger relative to the body midline (if correctly aligned with the cardboard electrode) can be computed, in angle. With other setting, the coordinates of the finger can also be registered by mean of a tactile screen (Gilligan et al., 2019).
* **Prism strength:** it varies between 8.5 and 17°, according to the studies. The larger the strength, the larger the after-effects (McIntosh et al., 2019). Although this relationship was indeed found with tasks involving proprioception of the right arm (PSA task, Line bisection task), it was not the case with a perceptual visual task (Landmark task, Michel & Cruz, 2015; Striemer et al., 2016).
* **Measurement of after-effects:** Traditionally PA after-effects are measured when after prism removal by means of three tasks: the visual straight ahead (VSA), the PSA, and the Open-loop pointing (OLP) task. These three tasks are thought to assess the visual, proprioceptive, and total (visual + proprioceptive) shifts, respectively (Hatada et al., 2006; Prablanc et al., 2020; Welch et al., 1974). As suggested by Prablanc et al. (2019), the PSA should be assessed with a passive movement of the arm in order to control for the motor component. Nevertheless, Hatada et al. (2006) have found no difference between the active and passive PSA immediately after prism removal. Besides these traditional tasks, the Landmark task have been extensively used from the early 2000’ in order to assess the *expansion* of the after-effects in other cognitive domains (Michel, 2016). Thus, LPA after-effects have been observed in the Landmark task (Colent et al., 2000), the Greyscale task (Loftus et al., 2009), the Number bisection task (Loftus et al., 2008), haptic perception (Girardi et al., 2004), and even on thermoregulation (Calzolari et al., 2016) and postural control (Michel et al., 2003). This expansion was also found in right brain-damaged patients, with therapeutic effects bearing on a large range of cognitive deficits (Jacquin-Courtois et al., 2013).

In sum, the procedure promoted by the team of Lyon can be used safely to determine the number of targets, target presentation, pace and order of pointing movements, and measurement of pointing error. This procedure can also be adapted on tactile screen if required. In all cases, the arm of the participant must be hidden in the starting position (terminal exposure), pointing movements must be rapid (and eventually paced by a metronome), and regular breaks (30 sec to 2 min) must be planned during the procedure. After-effects should be evaluated by at least on “sensori-motor” task (VSA, PSA, OLP), and eventually by one “perceptual” task (eg, Landmark task, Number bisection task, Greyscale task).

## Proprioceptive Straight-Ahead (PSA) task

The PSA task consists in asking the participant to point in the horizontal plane toward an imaginary line cutting the body and space in left and right parts. To do so, the participants put their hand at the chest level, and, the eyes closed, execute their pointing. The number of trials is usually five. In its passive form, the participant’s arm is moved on a table by the experimenter from left-to-right or right-to-left. The participants have to verbally indicates when their arm reaches the imaginary straight ahead. The PSA orientation (angle) or translation (cm) from the true body midline can be measured manually with a graduated table (angle), or automatically with a potentiometer device or a tactile screen (angle or cm, see Prism Adaptation).

## Landmark (LM) task

The LM task is classically considered as an allocentric task, because the participants must evaluate the shortest or longest segment of a split line. In the PA literature the LM tasks was used through different methods (McIntosh et al., 2019). Different parameters are involved in this variability:

* **Length of the line:** usually vary between 200 and 400 mm.
* **Viewing distance:** usually vary between 350 and 500 mm.
* **Position of the line:** The lines are presented either on a A4/A3 sheet or on a computer screen, and its positions are almost always centred with the body midline (Colent et al., 2000; Herlihey et al., 2012; Michel & Cruz, 2015; Striemer et al., 2016; Striemer & Danckert, 2010). Only McIntosh et al. (2019) have jittered the horizontal position of the line (+/- 1.5/3 mm) from the centre.
* **Duration of the line presentation:** generally, no time limit is imposed. For example, Michel and Cruz (2015) asked the participants to *“inspect the whole line”*. At variance, each line was flashed 500 ms in the experiment of Herlihey et al. (2012). The absence of flash might not be problematic, as no systematic oculomotor bias were found after PA in healthy subjects (Dijkerman et al., 2003; Gilligan et al., 2019).
* **Instruction:** Participants are required to judge which side is the shortest or the largest. In some experiments, these instructions are alternated (Schintu et al., 2014). The participants give their (binary) response verbally or by pressing a key.
* **Number of trials:** This number varies a lot between the studies, in function of the method of analysis. The number of trials is low (n=10) when the responses left/right are analysed as proportions (Striemer et al., 2016). Trials are more important (between 50 and 80 generally) when the Point of Subjective Equality (PSE) is extracted from a psychophysics function and used as dependent variable (Colent et al., 2000).
* **Bisection locus:** Lines are usually split at +/- 8, 4, 2, 1 and 0 (true centre) mm. Sometimes, the majority of the lines are presented at the true centre.
* **Cross of fixation:** For the computer version of the LM task, no cross of fixation is used. A mask is sometimes used between each line presentation (Herlihey et al., 2012; Schintu et al., 2017).

## Virtual Tilted Room (VTR)

This protocol is described in Odin et al. (2018):

* **Software:** “*Oculus Rift DK21HMD (Oculus, Menlo Park, CA, USA), which delivered the VV evaluation module generated by the software PosturoVR 0.8.3 (Virtualis, France). “*
* **Virtual environment:** There is two environments:*a dark-blue background without visual clues (called darkness);”* and *“a VTR in which participants were totally immersed as if they stood in a 3D tilted cube containing typical bedroom objects.”.* Importantly, the device is equipped with a gyrometer, so that the VTR is always tilted +/-18° away from gravity, regardless of any head movements. Regarding the spatial resolution, *“The virtual reality HMD was 1920 pixels wide X 1080 pixels high (960 X 1080 per eye) with a 1008 field of view.”*
* **Visual Vertical (VV) evaluation inside the VTR:**Each participant performs 8 trials (2 practice trials). The starting line orientation ranges randomly from -80 to 80°.” *In the VTR condition, the visual line appeared to be displayed on the front wall 3 m away, giving 1.80 m length and 1-cm width for a 338 angular size in the visual field.”* The lines keep the same dimensions in the darkness condition. The gyrometer of the device measures the VV orientation with a 0.2° accuracy.
* **Control of head movements:** *“the mean head orientation during each block of VV was monitored by use of an on- board accelerometer and gyroscope combined in one sensor, a gyrometer, the accuracy of which was 0.018.”.*

## Visual Vertical (VV) task

This protocol is described in Piscicelli et al. (2016).

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