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# Recalibration in functional perceptual-motor tasks: A systematic review

Milou Tessa Brand*, Rita Ferraz de Oliveira

*Sport and Exercise Science Research Centre, School of Applied Sciences, London South Bank University, 103 Borough Rd., SE1 0AA London, United Kingdom*

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ABSTRACT

Skilled actions are the result of a perceptual-motor system being well-calibrated to the appropriate information variables. Changes to the perceptual or motor system initiates recalibration, which is the rescaling of the perceptual-motor system to informational variables. For example, a professional baseball player may need to rescale their throws due to fatigue. The aim of this systematic review is to analyse how recalibration can and has been measured and also to evaluate the literature on recalibration. Five databases were systematically screened to identify literature that reported experiments where a disturbance was applied to the perceptual-motor system in functional perceptual-motor tasks. Each of the 91 experiments reported the immediate effects of a disturbance and/or the effects of removing that disturbance after recalibration. The results showed that experiments applied disturbances to either perception or action, and used either direct or indirect measures of recalibration. In contrast with previous conclusions, active exploration was only sufficient for fast recalibration when the relevant information source was available. Further research into recalibration mechanisms should include the study of information sources as well as skill expertise.

## 1. Introduction

Imagine you are a major league baseball pitcher expected to throw a strike ball each time you pitch. Halfway through the game your arm is getting slightly fatigued but you are expected to keep throwing your pitches. Your next throw may be a little off or outside the strike zone but you soon find the right adjustments and throw the ball accurately again. “Getting used to the fatigue” includes the rescaling of both the perceptual and the motor system and this process is known as *recalibration* (Withagen & Michaels, 2004, 2007). The aim of this systematic review is to analyse how recalibration can and has been measured and also to evaluate the literature on recalibration.

In the present review, recalibration has been defined in the context of the ecological approach. According to this approach, people directly detect the useful information available in the environment to guide their actions (Gibson, 1979). The proposal is that people do not detect the intrinsic properties of objects, but rather the informational variables that are specified by actions. That is to say, the information that is available in the environment is directly useful to guide the actions performed. In the context of ecological psychology, the accuracy of actions can be improved using attunement, calibration, and recalibration which we will define next (Jacobs, Vaz, & Michaels, 2012; Michaels & Carello, 1981; Withagen & Michaels, 2004).

From an ecological perspective, it has been proposed that during attunement, the person converges onto the most useful

* Corresponding author.
*E-mail address:* m.brand@lsbu.ac.uk (M.T. Brand).

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informational variable(s) that are available and can guide a successful action. Actions can be inaccurate because the person converged onto variables that are not optimal, meaning that they are not sufficiently specifying for a given action (Jacobs et al., 2012). However, through exploration, they may attune to those variables which result in consistently good performance (Michaels & Carello, 1981). For example, throwing to a target can be specified by variables that relate directly to the distance to the target such as the angle of elevation or declination (de Oliveira, Oudejans, & Beek, 2009; Ooi, Wu, & He, 2001). The attunement process by which people gradually change from detecting less useful to more specifying variables is also referred to as education of attention (Gibson, 1963; Gibson & Gibson, 1955; Jacobs et al., 2012). Attunement on its own may not always be sufficient because calibration is also required for actions to be successful (Withagen & Michaels, 2004).

Calibration is the second process involved in improving the accuracy of actions. From an ecological perspective, calibration is defined as the scaling of action to the perceptual information (Withagen & Michaels, 2004). Having attuned to using certain informational variables the person needs, subsequently, to scale their perception-action link to these informational variables. This calibration is only possible through practice and it is what maintains the appropriate relation between the informational variable and the perception or action (e.g., Jacobs & Michaels, 2006; Withagen & Michaels, 2002, 2004). In spite of important differences, the term calibration has often been used interchangeably with recalibration, including the only review on [re]calibration by Van Andel, Cole, and Pepping (2017). Calibration and recalibration may have been used interchangeably, because they are thought to be similar processes of scaling information to perception and action. However, the distinction is important, because they differ in terms of: a) what may elicit these processes; b) how long they may take to complete the process; c) what methods should be used to investigate them; and d) practical implications when calibration or recalibration are thought to underlie poor performance.

Recalibration happens only after a *disturbance* in either perception or action renders the perception-action link inaccurate, thereby initiating the rescaling of that link (rearrangement). For example, when a player's throwing requires an updated scaling of the perceptual-motor coupling due to fatigue. Recalibration is necessary to cope with different environments, using different tools, and coping with acute and long-term changes within the musculoskeletal system. Recalibration has been thought to largely depend on exploration (Withagen & Michaels, 2004, 2007) and a recent review concluded that even minimal movements may be sufficient for recalibration (Van Andel et al., 2017). The authors stated that recalibration occurred rapidly when there was a good match between the action that required recalibration and the movements that participants were allowed to make during exploration (e.g., when exploring maximal braking capabilities by experiencing braking in a car). On the other hand, when movements were restricted recalibration took longer. These conclusions were based on 4 articles and applied only to changes in action capabilities, so it is unclear whether the authors' generalization is warranted. Another review studied only changes in perception and consequent recalibration using prism glasses (Redding, Rossetti, & Wallace, 2005). They studied recalibration in a three-step process: a pre-exposure baseline, an active exposure to the prism glasses, and a post-exposure after-effect. In the present systematic review, we will review recalibration by including experiments that studied changes in both perception and action and we also include all the stages relevant for the study of recalibration.

Recalibration is a dynamic process that can be captured and measured at different points in time. Schematically, recalibration consists of five different measurable stages that can be useful to guide research into the process of recalibration. We propose Fig. 1 as an illustration of the recalibration process (extended from Redding et al. (2005)). It includes a (1) *baseline* where the perception-action coupling is calibrated for a given task. Measurement at baseline is crucial to establish that the skill is well-calibrated. A (2) *disturbance* in the perception-action coupling where performance is affected. This can be a disturbance directed at the action system or the perceptual system. After this, the (3) *rearrangement* period consists of rescaling perception and action to information. During this period performance can be measured trial-by-trial to capture for example whether recalibration is gradual or sudden. At (4) *removal* the disturbance is withdrawn and performance is affected again (often known as after-effect). The (5) *post-rearrangement* period consists of rescaling perception and action back to baseline levels. Again, trial-by-trial measurements can ascertain the time course of this stage. Different studies have measured different stages of this model. For example, Scott and Gray (2010) focused on

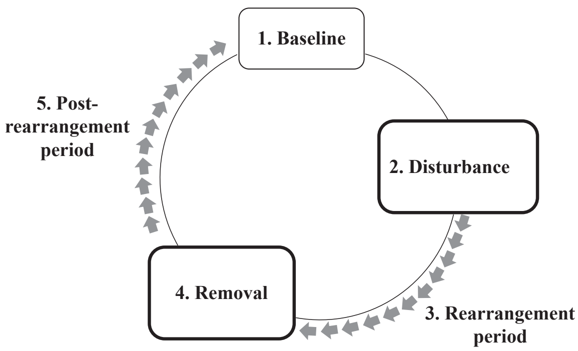


**Fig. 1.** Schematic illustration of strategies to measure recalibration. At (1) baseline, the perceptual-motor system is calibrated; (2) represents a disturbance to the perceptual-motor system; (3) in the rearrangement period each of the Gray arrows represents a trial or measurement of recalibration; (4) represents the removal of the disturbance and (5) in the post-rearrangement period each of the Gray arrows represents a trial or measurement of recalibration. Direct measures of recalibration include measures at (2) and (3) capturing both the disturbance and the rearrangement period. On the other hand, indirect measures of recalibration include measures at (1) and (4) capturing the baseline and the effects upon removal of the disturbance.