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A systematic review on perceptual-motor calibration to changes in action capabilities

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ABSTRACT

Perceptual-motor calibration has been described as a mapping between perception and action, which is relevant to distinguish possible from impossible opportunities for action. To avoid movement errors, it is relevant to rapidly calibrate to immediate changes in capabilities and therefore this study sought to explain in what conditions calibration is most efficient. A systematic search of seven databases was conducted to identify literature concerning changes in calibration in response to changes in action capabilities. Twenty-three papers satisfied the inclusion criteria. Data revealed that calibration occurs rapidly if there is a good match between the task that requires calibration and the sources of perceptual-motor information available for exploration (e.g. when exploring maximal braking capabilities by experiencing braking). Calibration can take more time when the perceptual-motor information that is available is less relevant. The current study identified a number of limitations in the field of perceptual-motor research. Most notably, the mean participant age in the included studies was between 18 and 33 years of age, limiting the generalizability of the results to other age groups. Also, due to inconsistent terminology used in the field of perceptual-motor research, we argue that investigating calibration in older cohorts should be a focus of future research because of the possible implications of impaired calibration in an aging society.

1. Introduction

The framework of direct perception suggests that movement is guided by one's perception of *affordances*; that is, the opportunities for action within an individual's environment (Gibson, 1979; Stoffregen, 2003). Perception of affordances logically requires scaling to action capabilities to allow distinction between the possible and impossible opportunities for action in an individual's surroundings. This scaling is known as *(perceptual-motor) calibration* (Bingham & Pagano, 1998; Warren, 1984; Withagen & Michaels, 2007).

Calibration has generally been observed in research considering the perception of affordances in a certain environment. In an experiment aimed at analyzing stair climbing behavior as a dynamical system, Warren (1984) was one of the first to study perception of affordances. In his seminal study, Warren (1984) assessed individuals' capacities to accurately perceive maximal and optimal climbable stair heights, given their own action capabilities. The results showed that, independent of their height, all participants perceived steps of 0.88 times their leg length to be their

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maximal climbable stair height. Furthermore, independent of the participant's height, a step that stood 0.26 times the participant's leg length in height was perceived to be the optimal stair height. These findings demonstrated that all participants used a scaling of their body size (in this case leg length) for perception of possibilities for action (in this case stair climbing), indicating that these participants were calibrated to their body size (given that body size is related to their action capabilities). Following the early work of Warren (1984), numerous other studies have focused on the perception of affordances and their scaling with action capabilities in different types of action (see Barsingerhorn, Zaal, Smith, & Pepping, 2012; for a historical overview).

Interested in the mechanisms of calibration, Bingham and colleagues (Bingham & Pagano, 1998; Bingham, Pan, & Mon-Williams, 2014; Coats, Pan, & Bingham, 2014) introduced the 'mapping' theory of calibration, which states that embodied units of perception are matched with embodied units of action. According to this theory, human motor control is governed by one's perception of the environment in terms of their own perception-action system. Calibration can be perturbed following a change of sensory units (e.g. changing the meaning of sensory information) and following action unit changes (e.g. manipulating stride length by adding weights to the body). Both types of manipulation have been considered by previous research.

Sensory units can be manipulated by disturbances of perceptual information. This has been extensively studied by experimentally manipulating information using a prism adaption paradigm (Bingham & Romack, 1999; Redding & Wallace, 1997). In general, these studies show that with practice and feedback, humans are able to adapt (*recalibrate*) to the new mapping. Fernández-Ruiz, Hall, Vergara, and Díaz (2000) studied adaptation to vision shifted by prisms and reported differences in learning rates between younger and older adults. Their older group of participants needed more practice before they completely recalibrated to the new mapping. While these studies do give an interesting insight into the mechanisms of calibration, it is important to note that such a manipulation is unlikely to occur in real life. Arguably, one of the few occurrences of changing the mapping in real life would be when a person starts to wear (multifocal-) glasses, but in this situation, the effects will be smaller compared to the experimental conditions (a person wears glasses with the aim of improving vision, not in order to challenge motor control).

The second way in which calibration can be perturbed is by a change in action capabilities. Changes in action capabilities occur naturally throughout the lifespan, such that as we mature from childhood to adulthood, we develop improved action capabilities and as we age, our capabilities decrease. In addition to these natural changes in action capabilities, one's capabilities can change more rapidly due to biological processes, such as the fatigue experienced by an athlete during a sports match that can decrease strength or running ability. Furthermore, action capabilities can be altered directly, by restrictions imposed by clothing or footwear. For instance, a person could put on shoes with high heels, which will directly influence step size. Considering that these changes could occur at any time, it could be argued that this would be the type of calibration that is predominantly required in everyday motor control.

Considering changes in action capabilities, decreases in capabilities seem to be especially relevant, since these decreases have been linked to the occurrence of falls in an older age bracket (Luyat, Domino, & Noël, 2008). Luyat et al. (2008) hypothesized that the higher incidence of falls in older adults could be the result of misperception of affordances, instigated by not adequately calibrating to the declines in physical function that are associated with aging. Plumert (1995) previously reported a link between decreased accuracy in the perception of action capabilities and a history of accidental injuries in children. Combined, these studies suggest that the falls experienced by older adults may be explained, at least in part, by an impaired capacity for these individuals to calibrate to the age-related changes in their action capabilities.

With the potential relevance of calibration for prevention age related accidents, such as of falls, it is of particular interest to consider what is required for an individual to calibrate to their capabilities. An improved understanding of this process may be of relevance to better understanding the mechanism(s) of age related accidents, as it is well known that their action capabilities decline with age, but it is currently unclear what is required for these individuals to recalibrate to age-related changes in action capabilities.

1.1. The current study

Collectively, the existing literature suggests that one's capacity to safely navigate their environment depends upon their ability to calibrate to changes in their action capabilities. Given this understanding, the current study focusses on the process of calibration to changes in action capabilities. Previous studies have reported that the process of calibration in general is highly dependent on exploration of the perception-action mapping (Adolph, Eppler, Marin, Weise, & Wechsler Clearfield, 2000; Barsingerhorn et al., 2012; Stoffregen, Yang, Giveans, Flanagan, & Bardy, 2009; Yu & Stoffregen, 2012) or feedback on performed movements (Bingham & Pagano, 1998; Withagen & Michaels, 2005). Yet individually, these theoretical studies do not consider practical issues, such as: the amount of exploration allowed; the amount of experience that is required for effective calibration; or the existence of individual differences in this process. The current study aimed to synthesize the existing literature on perceptual-motor calibration to changes in action capabilities with a focus on understanding the effectiveness of calibration.