



## Review

## Intentional binding and the sense of agency: A review

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## ARTICLE INFO

## Article history:

Received 16 September 2011

Available online 11 January 2012

## Keywords:

Sense of agency  
Intentional binding  
Voluntary action  
Forward model  
Prediction  
Sense of control  
Human agency  
Causality  
Actions  
Motor control

## ABSTRACT

It is nearly 10 years since Patrick Haggard and colleagues first reported the ‘intentional binding’ effect (Haggard, Clark, & Kalogeras, 2002). The intentional binding effect refers to the subjective compression of the temporal interval between a voluntary action and its external sensory consequence. Since the first report, considerable interest has been generated and a fascinating array of studies has accumulated. Much of the interest in intentional binding comes from the promise to shed light on human agency. In this review we survey studies on intentional binding, focusing, in particular, on the link between intentional binding and the sense of agency (the experience of controlling action to influence events in the environment). We suggest that, whilst it is yet to be fully explicated, the link between intentional binding and the sense of agency is compelling. We conclude by considering outstanding questions and future directions for research on intentional binding.

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## 1. Introduction

Humans are agents. That is, they have the capacity to bring about change in the external world through their own goal-directed behaviour. Often, humans also have a corresponding experience of this capacity, which is referred to as the ‘sense of agency’. A key challenge for scientific investigations of the sense of agency is the discovery and use of appropriate measures. In 2002, Haggard and colleagues introduced a novel measure of the sense of agency based on an intriguing relationship between voluntary action and subjective time (Haggard, Aschersleben, Gehrke, & Prinz, 2002; Haggard, Clark et al., 2002). This so-called ‘intentional binding’ measure has generated considerable interest and has been used in a number of experiments on the sense of agency. However, as a measure of the sense of agency it is not without its detractors (e.g. Buehner & Humphreys, 2009). We therefore feel that the time is right for a review of experiments using intentional binding to study the sense of agency. We first provide a brief historical background to the use of subjective time in Experimental Psychology. We begin by introducing Benjamin Libet’s seminal work and the ‘clock methodology’ he used (which forms the basis of the original intentional binding paradigm). Having set the scene we then review experiments using the intentional binding paradigm. We conclude this review by considering (a) the validity of intentional binding as a measure of the sense of agency, and (b) future directions for research.

### 1.1. The use of subjective time in Experimental Psychology: Libet’s work on volition

Measures based on the subjective experience of time have a long history in Experimental Psychology. In the 1880s Wilhelm Wundt developed his complication-clock apparatus to explore the time course of attention (Fig. 1). Participants had to orient to a clock (or pendulum) when presented with a certain stimulus (such as an auditory click) and report the onset of that stimulus by noting the position of the clock hand (or pendulum) when the stimulus occurred. Wundt observed systematic differences in the perceived onset of the auditory stimulus: People either perceived the auditory event earlier or later relative to the position of the clock hand (or pendulum). Moreover, this difference was attributed to whether participants were attending to the clock hand or to the auditory stimulus. Wundt’s chronometric methodology thus provides an invaluable tool for comparing subjective and objective stimulus onset timings.

In the 1980s Benjamin Libet adopted Wundt’s classic methodology to explore human volition. In Libet, Gleason, Wright, and Pearl’s (1983) seminal study, participants sat in front of a clock face marked at regular intervals. During each trial a spot rotated around the clock-face at a speed of 1 revolution every 2.56 s. Participants used the clock to judge the onset of certain events. In one condition participants flexed their wrist when they felt the urge, and judged the time they became aware of raising their hand. In a second condition participants again flexed their wrist when they felt the urge, and this time they judged the time they became aware of their conscious *intention* to raise their hand. In a third condition, a somatosensory stimulus was applied at an unpredictable time during the trial and participants judged the time that they felt this stimulus. To make these timing judgements participants reported the position of the spot on the clock face when they perceived the event (intention, action or somatosensory stimulus). Libet and colleagues concurrently used electroencephalography (EEG)

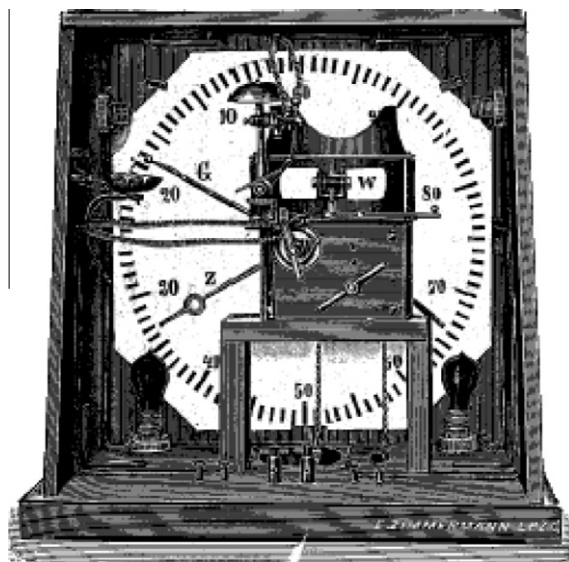


Fig. 1. The complication-clock apparatus developed by Wundt.

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