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# What subjective experiences determine the perception of falling asleep during sleep onset period?

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ABSTRACT

Sleep onset is associated with marked changes in behavioral, physiological, and subjective phenomena. In daily life though subjective experience is the main criterion in terms of which we identify it. But very few studies have focused on these experiences. This study seeks to identify the subjective variables that reflect sleep onset. Twenty young subjects took an afternoon nap in the laboratory while polysomnographic recordings were made. They were awakened four times in order to assess subjective experiences that correlate with the (1) appearance of slow eye movement, (2) initiation of stage 1 sleep, (3) initiation of stage 2 sleep, and (4) 5 min after the start of stage 2 sleep. A logistic regression identified control over and logic of thought as the two variables that predict the perception of having fallen asleep. For sleep perception, these two variables accurately classified 91.7% of the cases; for the waking state, 84.1%.



## 1. Introduction

Sleep onset period is defined as the transition from relaxed, drowsy wakefulness to unresponsive sleep. It has been observed that this period is associated with marked changes in a host of physiological and behavioral phenomena, as well as in subjective experience (Ogilvie & Wilkinson, 1984). Physiological phenomena associated with sleep onset include: decrease in high frequency electroencephalographic (EEG) activities (e.g., Azekawa, Sei, & Morita, 1990; Davis, Davis, Loomis, Harvey, & Hobart, 1937, 1938; Hori, 1985; Merica, Fortune, & Gaillard, 1991; Rechtschaffen & Kales, 1968; Tsuno et al., 2002); the absence and presence of different event-related potential (ERP) components (for review, see Campbell, Bell, & Bastien, 1992; Harsh, Voss, Hull, Schrepfer, & Badia, 1994); the appearance of slow eye movements (e.g., De Gennaro, Ferrara, Ferlazzo, & Bertini, 2000; Porte, 2004); the absence of elicited skin conductance responses (e.g., Johnson, 1970); a drop in the core body temperature and an increase in the distal skin temperature (e.g., Barrett, Lack, & Morris, 1993; Krauchi, Cajochen, Werth, & Wirz-Justice, 2000; Wehr, 1990); and, substantial, rapid reduction in respiration (e.g., Colrain, Trinder, Fraser, & Wilson, 1987; Naifeh & Kamiya, 1981). Behavioral indicators of sleep onset include: a decrease in sensory threshold, a cessation of responses to external stimuli (e.g., Anliker, 1966; Ogilvie & Simons, 1992; Ogilvie, Simons, Kuderian, MacDonald, & Rustenburg, 1991; Ogilvie & Wilkinson, 1984, 1988; Ogilvie, Wilkinson, & Allison, 1989; Simon & Emmons, 1956), and a decrease in muscle strength (e.g., Jacobson, Kales, Lehmann, & Hoedemaker, 1964; Litchman, 1974) were also observed in the course of the sleep onset process. And, as regards the subjective experience of sleep onset, loss of awareness of environmen-

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tal stimuli and the loss of control over thought processes have both been reported (e.g., Foulkes & Vogel, 1965; Gibson, Perry, Redington, & Kamiya, 1982).

Although these different phenomena are all associated with sleep onset, they are not always synchronized. Thus, the criteria for sleep onset identified for different studies are not consistent with one another. Most studies used physiological indices: for example, one of the most commonly used standards for sleep onset – the beginning of stage 1 sleep – is defined as the first 30-s epoch in which EEG alpha activities decrease to less than 50% (Rechtschaffen & Kales, 1968). Other studies, however, demonstrated that the subjective perception of falling asleep was more closely associated with stage 2 sleep, which is characterized by diminished responsivity to external stimuli. Webb (1980) reported that from 66.7% to 85% of those who were physically roused from sleep while in stage 2 sleep perceived this as awakening from sleep; the others did not feel as though they had been asleep. Even higher rates of discrepancy between physical arousal and the subjective perception of awakening were reported when assessments were made at the onset of stage 2 sleep: in several studies the percentage of those who felt as though they had been asleep was below 50% (Amrhein & Schulz, 2000; Hori, Hayashi, & Morikawa, 1994; Sewitch, 1984).

Naturally physiological definitions of sleep onset lend themselves to stricter methodological controls. Thus, they tend to be accepted as the standard indices of sleep onset. It is commonly assumed that physiological indications of sleep highly correlate with subjectively experienced sleep. Discrepancies between the two tend to be regarded as "sleep-state misperception." Regarding this as a "misperception" clearly implies that physiological measures are given greater weight. In daily life, by contrast, subjective perception is the most frequently used criterion for sleep onset. People typically judge the amount of time taken to fall asleep merely on the basis of our subjective experience, without the evidence of any objective indices. Relatively few studies, however, have focused on the subjective experiences that reflect sleep onset. Although a few previous studies have examined the correspondence between subjective experience and electrophysiological phenomenon during sleep onset, to the best of our knowledge, no study has explored the subjective experience that determines the perception of sleep onset.

Previous studies revealed that subjective experiences occurring during sleep onset include changes in thoughts, images, or sensations (for review, see Schacter, 1976). For example, Foulkes and Vogel (1965) collected 212 reports on the subjective experience of sleep onset from nine, young and healthy subjects, at four distinct junctures: continuous alpha EEG with rapid eye movements (REMs), discontinuous alpha EEG with slow eye movements (SEMs), descent into stage 1 sleep, and 0.5–2.5 min of stage 2 sleep. The aspects of subjective experience analyzed included sensory imagery, affect, thought control, and reality orientation. Foulkes and Vogel reported that sensory experiences were primarily visual, and remained so throughout the sleep onset period. Thought control and reality testing were found to decrease continuously during the process of falling asleep. Affective experience was minimal to begin with and then decreased even more after one had fallen asleep. Foulkes and Vogel concluded that hypnagogic experience – defined as a state of intermediate consciousness that precedes sleep – was quite similar to REM dream experience. This same pattern of changes in subjective experience was confirmed in other studies by the same research group (Vogel, Barrowclough, & Giesler, 1972; Vogel, Foulkes, & Trosman, 1966). Similarly, Gibson and his colleagues investigated subjective experiences associated with judgments that corresponded to physiological sleep states during the sleep onset period. They discovered that three cognitive criteria were significantly correlated with correct estimation of physiological sleep states; these three were thought control, awareness of surroundings, and temporal awareness (Gibson et al., 1982). More recently, a study utilized the absence of eyelid and head movements to define sleep onset and collected over 1000 reports of subjective experience from 11 subjects sleeping at home. The results were similar to those of previous studies in that they evinced a decrease in "wake-like" thoughts and an increase in dream-like mentations from 15 s to 5 min following sleep onset (Rowley, Stickgold, & Hobson, 1998).

Furthermore, other studies used a more data-driven approach to identify the cluster of subjective experiences that are associated with physiologically defined sleep onset. For example, a study used canonical correlations to investigate the correspondences between EEG states and subjective experiences, with subjects lying in bed during their typical bedtime. Results showed that peak power in 2–6 Hz and 13–15 Hz bands as well as low power in 9–11 Hz and 16–25 Hz bands were associated with a cluster of subjective experiences. These experiences included the perception of falling asleep along with other perceptual and cognitive variables, such as altered reality-remoteness, low familiarity, sudden ideas without goal-orientation, and lack of body perception (Lehmann, Grass, & Meier, 1995). Another study using principle component analysis identified a dimension of subjective experience that differentiated physiologically defined sleep states (stage 1 and stage 2) from waking states. The experiences that had the highest loading included the loss of awareness of the experimental situation, reported sleepiness, and inward directed attention (Wackermann, Pütz, Büchi, Strauch, & Lehmann, 2002). Although these studies did examine subjective experience during sleep onset, their main concern was to compare dream mentation to sleep onset experience, or to search for associations between subjective experiences and EEG activity. They did not attempt to identify the subjective experiences that determine the perception of falling asleep.

Previous studies have consistently demonstrated that sleep onset processes are associated with a decrease in awareness of environmental stimuli and with diminishing thought control. But they have not clearly identified precisely what factors are involved with the perception that we have fallen asleep. The primary goal of the current study is to probe the subjective experiences that are critical to this perception. Subjects were awakened at several junctures during sleep onset, in order to identify the various subjective experiences involved. Regression analyzes were then conducted in order to tease out those experiences that are decisive in explaining perception of sleep onset.