Facilitatory effects and behavioral benefits of nonconscious perception on human motor actions

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Abstract This review article deals with the facilitatory and beneficial effects of nonconscious perception on motor responses and actions in both primitive and real-world situations. First, the effects of nonconscious perception on motor responses in somatosensory and visual simple reaction time (RT) tasks with backward masking were examined. This showed that simple RTs were facilitated by the perception of given stimuli even if the performers were unaware of them under backward masking. Second, the so-called speed contagion effects on simple motor responses were examined, indicating that a prior observation of another individual’s fast motor actions facilitated simple RTs. Finally, evidence for the facilitatory effects of nonconscious perception on real-world situations was examined. This showed that penalty kicks may often be targeted toward the wider space in a goal area subdivided by the standing position of the goalkeeper, despite the lack of conscious awareness of which side was wider. These findings suggest that our perceptual judgment and motor control in both simple/primitive and real-world conditions are probably influenced in part by nonconscious and nonattended perception of stimuli provided in the environment. This is despite the fact that we tend to have the impression that our own behaviors are primarily governed by the conscious awareness of environmental conditions. Nonconscious perception may be primarily involved in our perceptual and motor actions and probably plays a role in advancing motor learning and control in daily activities and sports.

Keywords: nonconscious perception, motor action, reaction time

Introduction

Our motor actions in daily life and sports are generally performed on the basis of both the performer’s obvious intention to successfully perform them and a clear perception of environmental events. The performer’s attention may therefore generally be focused on particular events (or stimuli relevant to the events) that are crucial in the control of an ongoing action. However, such attended processes in motor actions may not always be effective for successful motor performance, but rather result in disruption\(^1\). In contrast, unattended stimuli/events may also be perceived without attention and could be used in performing actions adequately as well as advancing motor learning effectively\(^2\). Lewicki, Hill, and Czyzewska\(^3\) proposed theoretical considerations with evidence for nonconscious processing of information acquisition and encoding, which are much more general and in non-motor domains. They suggested that only a small portion of our mental activity, such as gathering information, learning, and thinking, is conscious and the majority is entirely unconscious. Furthermore, the nonconscious information-acquisition processes are much faster and structurally more sophisticated than consciously controlled cognition. This implies that nonconscioussness may form a dominant portion of perceptual and motor actions in both our everyday life and sports, more than our traditional belief that our behaviors are performed under conscious awareness of both ongoing events and the environment.

In this review article, the likely features of nonconsciousness in various aspects of our motor actions, such as motor responses in simple reaction time (RT) tasks and in sports, are examined. First, our recent findings\(^6\) that simple RTs are facilitated by nonconsciously perceived stimuli under backward masking are examined. Second, the so-called "speed contagion effects\(^10\)”, namely, the speeding-up of one’s own motor actions while seeing another person’s fast movements are examined. Finally, a typical practical sport example of nonconsciousness will be shown, indicating that the goalkeeper’s standing position in penalty kick situations often implicitly affects the direction of penalty kicks, with both the goalkeeper and kicker being unaware of the bias of the goalkeeper’s position\(^11\).

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Facilitatory effects of nonconscious perception on simple motor responses

Nonconscious perception has long been examined in the research field of perceptual psychology and psychophysiology by using backward masking paradigms. In a typical backward masking paradigm, a pair of a weak (prime) and a strong (mask) stimuli are consecutively presented with a short (e.g., a few or tens of milliseconds) interstimulus interval. This experimental manipulation often results in perceptual masking of the prime stimulus because of the mask stimulus in both visual\(^1^2-1^5\) and somatosensory\(^1^6-2^0\) modalities. For the motor domain, a prime stimulus facilitates motor responses in both visual\(^2^1-2^3\) and somatosensory\(^6,9,2^4\) RT tasks even when its perception is concealed by the mask stimulus under backward masking. This suggests that nonconsciously perceived stimuli can facilitate motor responses/actions even when the performer is unaware of the stimuli.

We\(^6,9\) examined the facilitation of motor responses under backward masking in a somatosensory simple RT task. As a prime stimulus, a weak electric stimulus of 0.2-ms (milliseconds) duration was delivered at the right wrist just above the median nerve at an intensity of 1.2 times higher than the individual’s perceptual threshold. For a mask stimulus, a strong electric stimulus of 0.2-ms duration and at intensities ranging from 4 to 5 times higher than the perceptual threshold was delivered at exactly the same place on the right wrist. The experimental hypothesis was that if the weak (prime) stimulus, masked by the strong (mask) stimulus, facilitated motor responses, the resultant RTs under backward masking should be shorter than those under conditions where a strong stimulus alone was presented. In contrast, if motor responses were simply performed in response to the consciously perceived stimulus, the resultant RTs should not differ for the backward masking (i.e., both the weak and strong stimuli were presented) and the condition where the strong stimulus alone was presented. Our results clearly showed that somatosensory RTs under backward masking were significantly shorter than those under the strong stimulus alone (Fig. 1). This suggested that simple motor responses can be facilitated by a weak stimulus even when the performers are unaware of it. Similar findings were also evident for visual RT tasks\(^7,8\), suggesting that the facilitation effects of nonconsciously perceived stimuli on motor responses generally occur in both somatosensory and visual modalities.

![Facilitation effects of nonconscious perception of stimuli under backward masking on somatosensory RTs.](image)

*Fig. 1* Facilitation effects of nonconscious perception of stimuli under backward masking on somatosensory RTs. (a) Experimental situations with weak and strong electric stimuli provided with a 40-ms interstimulus interval and simple key-press responses. (b) RTs for the backward masking condition (both the weak and strong stimuli were provided) were significantly shorter than the RT for the condition of strong stimulus alone ($t(8) = 7.25, p < 0.001$).
Speed contagion effects of human actions on simple motor responses

Our motor actions are often affected by other people’s actions, particularly in action speeds. For example, an individual who is walking tends to slow down while seeing the actions of elderly people\(^{25}\). Such assimilation or speed contagion effects can be explained in terms of the mirror neuron system, which was first proposed by Rizzolatti, Fadiga, Gallese, and Fogassi\(^{26}\). This assumes that the premotor and other cortical areas relevant to the activation of an intended motor action (e.g., grasping a cup) are also facilitated/activated while simply seeing another individual’s motor action that is similar to the intended motor action. Although the mirror neuron system has been thought to be activated for intended rather than unintended/primitive actions, it has recently become evident that seeing another person’s action facilitates individual simple/primitive motor responses as well. Watanabe\(^{10}\) showed that simple visual RTs were shortened on prior observation of a fast biological motion (i.e., the motion of a set of light-reflective markers attached on the body in the dark), suggesting that mirroring or speed contagion effects occur in primitive motor responses rather than daily/sport and intended ones.

We (unpublished data) have also recently examined likely speed contagion effects in a pseudo-real-world situation, using animated jogging at slow (2.5 steps/s [second]) and fast (7.5 steps/s) speeds. Our primary interest in this study was whether the speed contagion effects occurred in both visual and auditory modalities. To this end, we used a 2-sec-long jogging animation and/or footstep tones presented in advance, and this was immediately followed by a simple RT task (Fig. 2a). In the simple RT

![Fig. 2](image)

**Fig. 2** Speed contagion effects of slow (2.5 steps/s) and fast (7.5 steps/s) jogging animations with or without footstep tones. (a) Participants first observed either the jogging animation alone, jogging animation with footstep tones, or footstep tones alone for 2 s, then performed a simple RT task in which the fixation cross changed in luminance and the participants responded to this by pressing a key. (b) The mean RT for the fast condition was significantly shorter than that for the slow condition in the animation alone (Vision) condition \((F(1, 24) = 7.959, p < 0.01)\), with a significant slow-fast difference for neither the footsteps alone (Audition) nor the animation plus footsteps (Vision + Audition) condition.
task, a fixation cross was presented first and, after a short interval (varying randomly in the range of 300 to 1200 ms), the luminance of the fixation cross diminished to 50% of its luminance intensity. Responding to the change in luminance of the fixation cross, the participants were asked to press a key as fast as possible. The simple RT task was conducted in three animation/footstep conditions: animated jogging with footstep clicks (vision plus audition), animated jogging with no footstep clicks (vision alone), and footstep clicks with no animated jogging (audition alone). Our results (Fig. 2b) showed that RTs were significantly shorter for fast compared to slow animated jogging, but this appeared only in the vision-alone condition. No difference in RTs for the fast and slow speed conditions appeared in the audition-alone condition. In the vision-plus-audition condition (i.e., a condition more naturally depicting daily behaviors), RTs for fast jogging were only slightly shorter than those for slow jogging with no significance. Our findings suggest that the speed contagion effects of other individual actions on simple RTs may be vision specific. It is therefore evident that human actions/movements are affected by seeing (not hearing) another person’s actions/movements, even though the performer does not explicitly focus his/her attention on them.

Nonconscious influence of a goalkeeper’s standing position on the direction of penalty kicks

The facilitatory effect of nonconscious perception on motor responses/actions is evident in much more practical motor behaviors as well. A typical example was shown by Masters et al.11), who examined 200 video clips of penalty kicks in international soccer games. They showed that in 96% of the video clips, the standing position of goalkeepers deviated from the goal center to either the left or right by 9.95 cm on average, and that about 60% of the penalty kicks were directed toward the wider space of the goal area. This was further examined by a series of psycho-perceptual experiments, using a goal (plus a goalkeeper) picture presented on a computer monitor (scaled to 3% of the real soccer goal width) with left-right off-center deviations of the goalkeeper’s standing position randomly manipulated to vary in the range of 0.5 to 20% of the whole goal width (Fig. 3a). Participants were asked to judge which was the wider side determined by the goalkeeper’s position and to indicate the extent of their confidence in their judgment. Their results showed, again, a relatively high percentage (higher than 60%) of correct judgments on the wider area, with the same low self-confidence in their judgment. This has recently been replicated and extended to expert soccer players by Weigelt, Memmert and Schack27). They suggest that processing of implicit stimulus information influences the selection of shooting direction in soccer penalty situations and that this occurs even in experts as well as novices.

The findings of both Masters et al.11) and Weigelt et al.27) imply that our conscious and nonconscious perception of the environment may somehow be dissociated, and that the nonconscious perception largely contributes to producing correct motor actions and judgments. Most importantly, this occurs not only in experimental situations but also in practical situations such as soccer penalty shooting.

Conclusions

In this review article, the effects of nonconscious perception on simple motor responses and real-world actions were examined in three sections. First, we showed our recent experimental findings of simple somatosensory and visual RT tasks under backward masking, indicating clear facilitation effects of nonconscious stimuli on simple RTs even with a lack of awareness of the given stimuli. Second, evidence for the facilitatory effects of non-attended background stimuli of another individual’s...
motor actions on motor responses was examined. This showed that while seeing fast human actions in advance, simple RTs were shortened, despite the preceding human actions having nothing to do with the following simple RT tasks. Finally, the off-centered standing position of the goalkeeper in soccer penalty kick situations clearly, but implicitly, affected the direction of penalty kicks, despite the lack of conscious awareness of which side was wider. These findings suggest that our perception, judgment, and motor actions are affected by nonconscious/nonattended environmental stimuli in both simple and real-world conditions, although we have an impression that our behavior is performed only with conscious awareness. Better understanding the nonconscious nature of our behavior may well provide a great help in advancing motor learning and control in daily life and sports. Further studies will be needed to elucidate the nature and functions of nonconscious perception on motor actions in further detail.

Acknowledgments

The original manuscript of this review article was reviewed by Drs. Masami Ishihara (Tokyo Metropolitan University) and Yasuhiro Seya (Ritsumeikan University). I greatly appreciate their careful, critical, and insightful comments on the original manuscript. This review work was supported in part by JSPS KAKENHI Grant Numbers 24650392 and 25242060.

References