

CONFORMITY BIAS INFLUENCE ON WALKING SPEED IN A SMOKE-FILLED TUNNEL EXPERIMENT

¹Miho Seike, ²Wenhao Li, ³Takao Futagami

¹University of Tsukuba, JP

²Liaodong University, CN

³Shinshu University, JP

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ABSTRACT

The influence of information from people—referred to as conformity bias in this study—during an actual evacuation owing to a tunnel fire has not been clarified, despite the high number of people present in the same area during such an event. Therefore, in this study, we conducted an experiment focusing on the peoples' behavior upon seeing another evacuee moving in the wrong direction.

The test was conducted using a full-scale road tunnel (50 m in length and 6 m in width) in the Fukushima robot test field. We simulated a darkened environment caused by smoke. The smoke was a mixture of water and glycol, ensuring it was non-irritant and non-toxic. Many tunnels in Asia, including Japan, have not installed a guide light function other than the guide board. Obstacles were set-up in the form of a small truck and van. The participants were not informed that a person moving in the wrong direction (staff member) would pass them along the way. Walking speed was calculated based on the speed before the participant encountered the staff member and after the encounter. The participants were made up of 20 men (average age of 42.6 years). The speeds of 12 participants (60%) decreased after the staff member had passed them.

Keywords: Tunnel, smoke, human behaviour, risk analysis, fire.

1. INTRODUCTION

During actual evacuations due to tunnel fires, a significant number of individuals are often present in the same vicinity. The presence of others can provide reassurance to evacuees, which can have both positive and negative implications for the efficiency of the evacuation process. Helbing et al. [1] identified nine characteristics of escape panic, one of which is the tendency for individuals to exhibit group behavior, meaning they often mimic the actions of others. This behavior is considered a response to unexpected dangerous events. Nilsson et al. [2] and Abe [3] reported that observing fellow evacuees can induce conformity behavior, characterized by fleeing simply because others are doing so. Synchronicity, as defined by Jung [4], refers to a causal coincidence that holds significant meaning for the individual experiencing it. Hanson and Klimo [5] posited that synchronicity is a goal-oriented phenomenon that occurs independently of an individual's conscious control, emphasizing the recognition of personal experiences and meaningful coincidences. Planer [6] asserted that synchronicity is unpredictable and cannot be the result of intention, underscoring the profound connection between an individual's mind and external events.

Classical conformity is a form of social influence wherein an individual modifies their behavior or attitudes in response to the actions, attitudes, or expectations of others, including adherence to perceived group norms. The seminal studies on classical conformity by Muzafer Sherif and Solomon Asch illustrate the significant impact of social pressure. Conformity can exert both beneficial and detrimental effects on leadership. Specifically, within leadership contexts, conformity can facilitate decision-making and enhance group cohesion, yet the pressure to conform may also lead to distorted thinking. In an experiment concerning tunnel fires, Nilsson et al. [2] discovered through full-scale evacuation experiments that individuals tend to evacuate upon observing others doing so, and that the actions of individuals influence the behavior of others. However, a pertinent question arises: if individuals observe someone acting contrary to what they believe is correct, how will they respond? The influence of information conveyed by individuals—termed conformity bias in this study—remains unclear. Consequently, this study conducted an experiment focusing on the behavior of individuals after observing another evacuee moving in the wrong direction.

2. EXPERIMENTAL SET-UP

In this study, experiments were conducted at the Fukushima robot test field (Figure 1). The tunnel dimensions were 50 m in length, 6 m in width, and 6 m in height. Consistent with previous studies [7–12], we utilized artificial smoke that was non-irritating and non-toxic, generated from a mixture of water and glycol. Ten smoke generators (PORTA SMOKE PS-2005; Dainichi, Japan) were strategically placed within the tunnel at intervals of 15 m, with a fan positioned in front of each generator to facilitate smoke diffusion. The diffusion state was visually inspected, and smoke density measurements were verified by the experimental staff prior to each experiment. The extinction coefficient (smoke density (C_s)) was quantified using four laser sensors (LV-NH100; Keyence, Japan), as outlined in previous studies [7–12]. Smoke density measurements were recorded at coordinates $(x, y) = (10.5, -3.8)$, $(26.8, 3.8)$, $(35.5, 3.8)$, and $(45.6, 3.8)$ at a height of 1.5 m (refer to Figure 2). The target C_s value was 1.0 m^{-1} .



Figure 1: Experiment conducted in a full-scale tunnel

The study comprised 20 male participants, ranging in age from 23 to 64 years, with a mean age of 42.6 years. Participants were instructed to don a safety vest, mask, helmet, and a wearable camera (Panasonic HX-A100). Additionally, each participant was provided with an Apple iPod (series 6) equipped with a flashlight function to simulate the illumination of a smartphone. Informed consent for participation in the study was obtained through a paper-based form, which received approval from the Ethics Committee (Ethical Committee for Epidemiology of Hiroshima University, E2021-2457).

3. SCENARIO AND HYPOTHESES SETTING

In this study, we deliberately introduced individuals moving in the opposite direction to that which evacuees perceived as correct, with the aim of creating uncertainty in directional information and examining the consequent changes in speed. This experiment involved participants who had no prior experience of evacuating in complete darkness filled with smoke, as would occur in a tunnel fire. It was hypothesized that encountering individuals moving in what was perceived as the "wrong" direction in an unfamiliar environment would induce psychological disturbance.

Figure 2 illustrates the experimental procedure. Initially, subjects moved from the starting point to the goal. They were instructed to reach the goal, press a button, and then return to the starting point, without being informed that staff members would be passing by along the route. The dotted lines represent the walking path of the staff members. The staff, attired identically to the evacuees, commenced walking just before the evacuee reached the van, moving at approximately 1.3 m/s, and consistently passed alongside the evacuee at a distance of about 1.0–1.5 meters. In instances where evacuees evacuated while touching the van, the staff passed by next to them. In this paper, observing individuals moving in the opposite direction is defined as the conformity bias, and the effect of this was investigated. Based on these scenarios, the following hypothesis was established: Hypothesis: Individuals moving in the opposite direction increase the uncertainty of directional information.

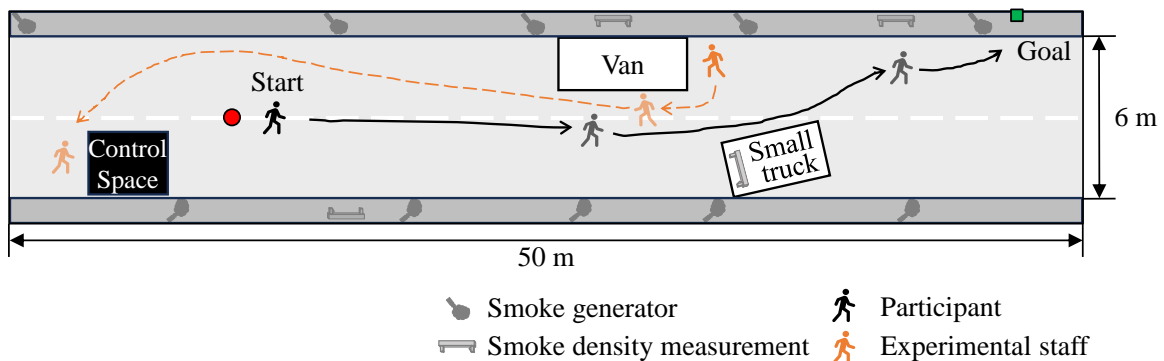


Figure 2: Experimental set-up and participant route
(vertical axis denotes width and horizontal axis denotes tunnel length)

4. RESULTS

Figure 3 illustrates the average walking speeds recorded before and after participants encountered the staff member, revealing a reduction of approximately 0.1 m/s. A summary of these walking speed results is presented in Table 1. T-tests conducted for each group indicated a statistically significant difference in walking speeds before and after the encounter at the 5% significance level. Figure 4 presents a scatter plot of walking speeds before and after the encounter with the staff member. The black dashed line represents a gradient of 1, serving to confirm any increase or decrease in speed, while the red solid and dashed lines denote the regression line and the 95% confidence intervals (2.5% and 97.5%), respectively. Data points situated above this line signify an increase in speed. Of the 20 participants, eight exhibited an increase in speed, whereas the remaining 12 demonstrated a decrease. Participants were categorized into 'speed increase' and 'speed decrease' groups, and significant differences were assessed before and after the encounter using t-tests. The initial speed of the 'speed decrease'

group was the highest at 0.82 m/s, which decreased by 0.22 m/s to 0.60 m/s after the encounter. This speed was also greater than that of the 'speed increase' group. The 'speed increase' group initially reduced their speed to 0.40 m/s, followed by an increase of 0.08 m/s. Although a significant difference between the 'speed increase' and 'speed decrease' groups was observed at the 0.1% level prior to the encounter, no significant difference was detected post-encounter. Furthermore, within both the 'speed increase' and 'speed decrease' groups, significant differences in speed before and after the encounter were observed at the 5% and 0.1% levels, respectively.

Figure 5 and Table 2 illustrate the heart rate (HR) measurements recorded before and after the interaction with the staff member. The mean HR exhibited a reduction of approximately 0.7 bpm; however, no statistically significant difference was detected between the pre- and post-encounter HR values. Additionally, Figure 6 depicts the relationship between HR and speed ratios before and after the encounter. It is noteworthy that, when comparing the current HR findings with the exercise-induced HR formula at a walking speed of 1.33 m/s as provided by Bassey et al. [13]—which is calculated based on an individual's height and weight—16 out of the 20 participants in this study demonstrated a higher HR than those reported by Bassey et al. [13]. Consequently, the observed HR changes in participants are unlikely to be attributed to physical exertion and are more plausibly linked to psychological factors. Pearson correlation analysis yielded a correlation coefficient of 0.52 (p-value = 0.019), signifying a significant result at the 5% significance level. Furthermore, an increase in speed was observed concomitant with an increase in the HR ratio.

5. DISCUSSION

The findings align with the hypothesized influence of social conformity-related processes on walking behavior in contexts of directional ambiguity. Contrary to inducing uniform behavioral alignment, the presence of counter-directional walkers prompted varied motor responses. Notably, 60% of participants exhibited a statistically significant reduction in walking speed. A significant correlation between speed ratio and HR ratio was also identified, indicating a link between motor adjustment and physiological arousal. Crucially, the observed

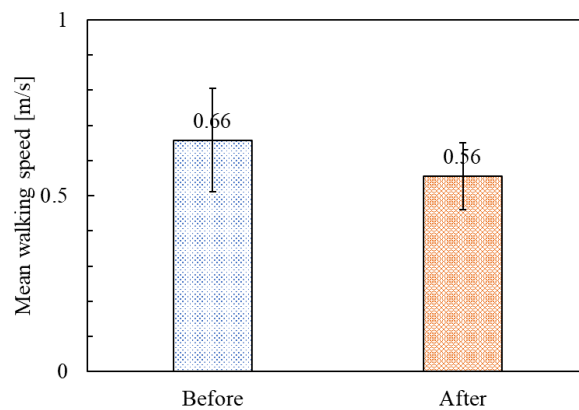


Figure 3: Mean walking speed (before and after)

Table 1: Walking speed (before and after)

	Before	After
Mean	0.66	0.56
Min	0.23	0.32
Max	1.59	1.27
Standard deviation	0.31	0.20
95%CI	0.15	0.10
p-value	0.017	
t-value (a two-tailed)	2.093	

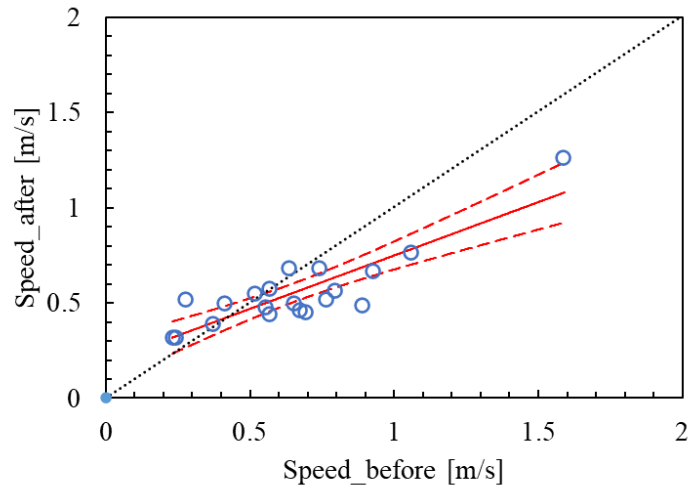


Figure 4: Scatter plot of walking speed (before and after)
 Pearson correlation 0.87 ($p = 8.34 \times 10^{-7}$)

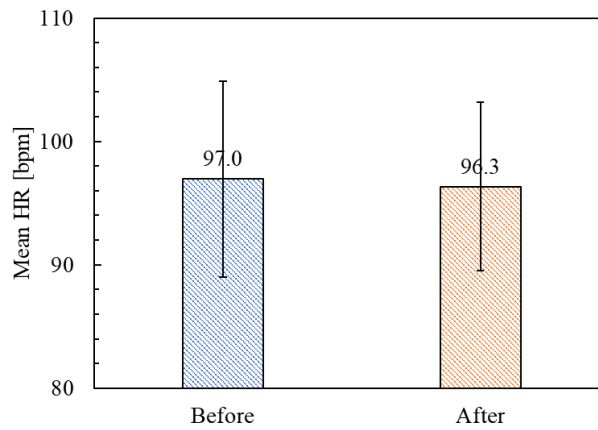


Figure 5: Mean heart rate (HR; before and after)

Table 2: HR (before and after)

	Before	After
Mean	97.0	96.3
Min	49.8	58.0
Max	128.3	119.2
Standard deviation	17.0	14.6
95%CI	7.94	6.84
p-value	0.621	

decrease in walking speed does not signify complete behavioral conformity, such as directional reversal, but rather reflects cautious modulation in response to socially induced directional ambiguity. The bidirectional pattern of speed change suggests that while directional ambiguity heightened arousal, it did not result in uniform behavioral outcomes. This divergence can be interpreted through Gray's Reinforcement Sensitivity Theory, which

suggests that individuals vary in their engagement of inhibitory and activation systems [14] when faced with ambiguity or conflict. In such scenarios, stronger inhibitory engagement may lead to cautious deceleration, whereas activation-oriented tendencies may promote urgency-driven acceleration. Nonetheless, these interpretations should be regarded as preliminary, given that dispositional sensitivity systems were not directly assessed and the sample was limited to 20 male participants. Future research incorporating personality measures and more diverse samples is essential to elucidate the mechanisms underlying these heterogeneous responses.

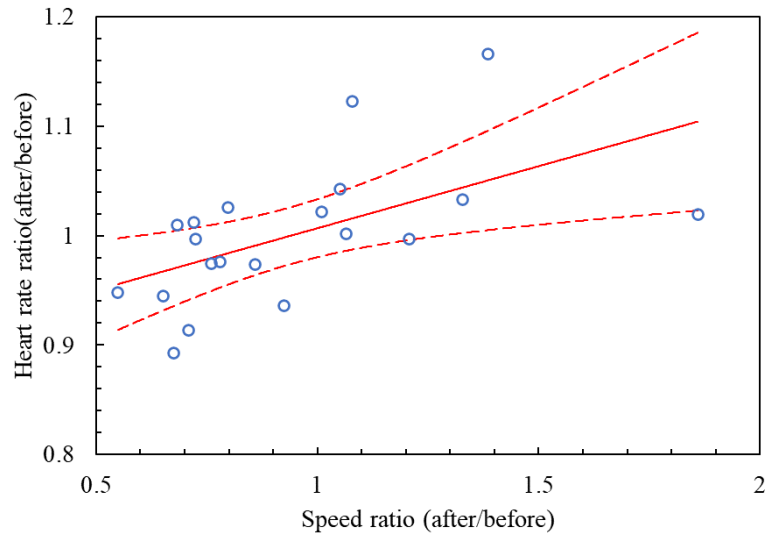


Figure 6: Relationship between the speed ratio and HR ratio
Pearson correlation 0.52 ($p = 0.019$)

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