What Would Be Usain Bolt’s 100-Meter Sprint World Record Without Tyson Gay? Unintentional Interpersonal Synchronization Between the Two Sprinters

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OBSERVATION

What Would Be Usain Bolt's 100-Meter Sprint World Record Without Tyson Gay? Unintentional Interpersonal Synchronization Between the Two Sprinters

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Despite the desire of athletes to separate themselves from their competitors, to be faster or better, their performance is often influenced by those they are competing with. Here we show that the unintentional or spontaneous interpersonal synchronization of athletes' movements may partially account for such performance modifications. We examined the 100-m final of Usain Bolt in the 12th IAAF World Championship in Athletics (Berlin, 2009) in which he broke the world record, and demonstrate that Usain Bolt and Tyson Gay who ran side-by-side throughout the race spontaneously and intermittently synchronized their steps. This finding demonstrates that even the most optimized individual motor skills can be modulated by the simple presence of another individual via interpersonal coordination processes. It extends previous research by showing that the hard constraints of individual motor performance do not overwhelm the occurrence of spontaneous interpersonal synchronization and open promising new research directions for better understanding and improving athletic performance.

Keywords: interpersonal coordination, sprint, unintentional, entrainment

In individual sports competition we strive to separate ourselves from those around us, to be better, faster, and greater than our competitors. Despite this desire, our athletic performance is often influenced by the performance of those we compete with. Individuals often run slower or faster, jump higher or lower, or hit the ball straighter and harder depending on how well or poorly their rival or adversary is performing. It is well known that these modifications of performance can be explained, in part, by the psychological aspects of competition, such as social facilitation, mental focus or competitive anxiety (Martens, Vealey, & Burton, 1990; Zajonc, 1965). These factors, however, do not always account for the variability associated with the athletic performance and it remains unclear why the motor skills that athletes perform repeatedly during practice suddenly change when performed in the presence of competitors. Here, we demonstrate how these modifications can result from athletes unintentionally or spontaneously synchronizing their movements with the movements of their competitors.

The phenomenon of behavioral synchronization underlies the dynamics of many different biological systems ranging from groups of neurons to groups of people (Pikovsky, Rosenblum, & Kurths, 2001; Strogatz, 2003). The movements of two or more individuals often become spontaneously or unintentionally synchronized when coupled via perceptual (e.g., visual, auditory) information (Néda, Ravasz, Brechet, Vicsek, & Barabási, 2000; Schmidt, Carello, & Turvey, 1990; Schmidt & O'Brien, 1997; Schmidt & Richardson, 2008; Tognoli, Lagarde, DeGuzman, & Kelso, 2007). Nearly everyone has experienced this when walking side-by-side with a friend or family member, with one's strides moving together in time and space with those of their cowalker (Nessler & Gilliland, 2009; van Ulzen, Lamoth, Daffertshofer, Semin, & Beek. 2008). Such spontaneous synchronization can influence the preferred spatiotemporal patterning of individuals' movements. That is, individuals naturally walking at faster frequencies tend to spontaneously walk at slower frequencies whereas individuals naturally walking at slower frequencies tend to spontaneously walk at faster frequencies (Nessler & Gilliland, 2009; Schmidt & Richardson, 2008; van Ulzen et al., 2008). Recent research has also demonstrated that the global stride dynamics of the cowalkers can be influenced by behavioral synchronization; such that cowalkers spontaneously adopt a similar structure in cycle-to-cycle movement variability

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(Marmelat, Deligniègres, Torre, Beek, & Daffertshofer, 2014). Such synchronization, however, only occurs when the difference between the preferred or natural movement frequencies of the individuals is small enough to be compensated by the perceptual coupling (Lopresti-Goodman, Richardson, Silva, & Schmidt, 2008; Schmidt & O'Brien, 1997). Otherwise, individuals just move in time and space totally independently of each other and no spontaneous synchronization or entrainment occurs. That latter point, explains why 1:1 frequency locked synchronization only rarely occurs between two walkers that have different leg lengths because they have different natural or preferred stride frequencies (Nessler & Gilliland, 2009).

These dynamical entrainment processes have been not only demonstrated between cowalkers but also in numerous interpersonal situations involving a variety of body and limbs movements (Issartel, Marin, & Cadopi, 2007; Néda et al., 2000; Richardson, Marsh, Isenhower, Goodman, & Schmidt, 2007; Schmidt & O'Brien, 1997; Tognoli et al., 2007; Varlet, Marin, Lagarde, & Bardy, 2011). Some studies have also revealed these interpersonal entrainment processes in sport activities such as basketball, tennis, and football (Araújo, Davids, Bennett, Button, & Chapman, 2004; Davids, Button, Araújo, Renshaw, & Hristovski, 2006; Duarte et al., 2013; McGarry Anderson, Wallace, Hughes, & Franks, 2002; Palut & Zanone, 2005; Travassos, Araújo, Vilar, & McGarry, 2011). In particular, previous research has shown that the displacement trajectories or coordinated behaviors of individuals playing together or against each other can be understood to be constrained by dynamical entrainment processes (McGarry et al., 2002). Despite this growing body of evidence, the robustness of these interpersonal synchronization processes during everyday situations, and sport activities more specifically, remains questionable. A major limitation of the previous work is that investigations were mostly restricted to laboratory tasks where no individual motor behavior or performance was threatened by the occurrence of spontaneous interpersonal coordination. Would two individuals synchronize their movements if it might affect how well they could run or jump for example? One would expect that the hard constraints of individual motor performance would negate or overwhelm the occurrence of spontaneous interpersonal synchronization, especially when the success of the individual task requires maximum psychophysiological resources. In particular, one would assume that the hard constraints on the movements of sprinters to ensure efficient foot–floor contacts, acceleration, and maintaining the highest levels of speed against the onset of fatigue would prevent the occurrence of synchronization. In the current study we further demonstrate the robustness of spontaneous interpersonal synchronization processes by showing how synchronization has even occurred during one of the greatest individual sport performances of the century—the 100-m final of Usain Bolt in the 12th IAAF World Championship in Athletics (Berlin, 2009), in which he broke the world record.

After wining the semifinal in 9.89 s, Usain Bolt won the final in 9.58 s and established a new world record. He ran throughout the race side-by-side with Tyson Gay on his right side, who finished second in 9.71 s and won the other semifinal in 9.93 s. Although they ran side-by-side, Usain Bolt and Tyson Gay had no reason to be synchronized during the race. Moving in synchrony might have affected their preferred behaviors and how fast they ran, and accordingly, one would expect the two sprinters to have sufficient experience to avoid such a perceptual or external influence. Furthermore, it was even more unlikely that the movements of the two sprinters became synchronized during the race because they have two totally different preferred stride frequencies (Nessler & Gilliland, 2009; Richardson et al., 2007; Schmidt & O'Brien, 1997). Indeed, Usain Bolt is taller than typical elite sprinters (i.e., 196 cm), and hence, he has slower movement frequency and much longer strides. He crossed the finish line in only 41 and 40 steps in the final and semifinal, respectively, while Tyson Gay (180 cm tall) performed 45–46 and 44–45 steps, respectively. However, an examination of the steps of the two sprinters during the final contrasts with these expectations and shows that Usain Bolt and Tyson Gay spontaneously and intermittently synchronized.

Method

Using a frame-by-frame video analysis, the synchronization that occurred between the two sprinters during the final was determined by extracting the time occurrence of each of their steps, defined as the frame number corresponding to the first contact to the ground. The steps of the two sprinters were also extracted from their respective semifinal to obtain a control synchronization (i.e., a synchronization that does not occur because of a perceptual coupling but simply because the two sprinters performed the same task at the same time). All videos analyzed were sampled at 30 fps and the two semifinal videos were synchronized in time (i.e., synchronization of the first frame of each race) before extracting the steps. The time occurrences of the steps of the two sprinters were determined separately and each video was analyzed by two examiners. The frame numbers selected by the two examiners were averaged when they were different (9% of the total number of steps extracted with no difference greater than one frame).

The synchronization between the steps of the two sprinters was then examined by computing the corresponding relative phase. Typically used to measure synchronization (Kelso, 1995; Pikovsky et al., 2001), relative phase captured the relative timing between the steps of the two sprinters. Usain Bolt was taken as reference to compute the relative phase because he has a lower stride frequency and thus performed fewer steps during the races than Tyson Gay. The relative phase was computed as

$$\phi = \frac{t_B - t_G}{T_B} \times 360°,$$

where t_B and t_G were the time of each step of Usain Bolt and Tyson Gay, respectively, and T_B was the time between two successive steps of Usain Bolt. Accordingly, one relative phase value was obtained for each step of Tyson Gay. Relative phase values were then normalized between −180 and 180. Perfect step synchronization therefore corresponded to relative phase values of 0°, irrespective of the lateralization of the steps (right or left) of the two sprinters.

Relative phase angles were expected to continuously drift over time due to the difference between the preferred movement frequencies of the two sprinters, but with slowdowns or intermittent phase locking around 0° if synchronization occurred. Synchronization should thus result in nonuniform relative phase distributions with more values around 0° in contrast to flat or quasiflat (i.e., uniform) distributions expected if no synchronization occurred, as all phase regions should be equally explored (Lopresti-Goodman et al., 2008; Richardson et al., 2007; Schmidt & O'Brien, 1997). The distributions were obtained by computing the percentage of occurrence of the last 37 relative phase values (of 45 values) of the final and semifinal time series across nine 40° phase regions from −180 to 180°. The first values of the final and semifinal relative phase time series were removed to avoid increasing artificially the number of values around 0° that simply occur because the two sprinters started at the same time.

However, with only one trial and few relative phase values (i.e., 37), high or relatively high percentages of occurrence for a specific phase region can still simply occur by chance. Therefore, we randomly generated 100,000 relative phase distributions of 37 values between −180° and 180°. The averaged distribution of these 100,000 distributions is represented on Figure 2 and illustrates a perfect random (uniform) relative phase distribution. These 100,000 distributions were then used to test statistically whether percentages of occurrence observed in the final and control semifinals were significantly higher than chance. The 100,000 values obtained for each phase region were sorted and the 99,900th highest value was used as a 0.01 significance threshold. This value was identical for the nine phase regions and was equal to 24.32%. We considered that percentages of occurrence greater than this value in the final or semifinal distributions indicated the occurrence of spontaneous synchronization between the two sprinters.

Results and Discussion

As can be seen from an inspection of Figure 1, after starting at or close to 0° because the two sprinters obviously began moving at (relatively) the same time (just after the start gun), both the final and control semifinal relative phases drift as expected due to the difference between their preferred stride frequencies (Nessler & Gilliland, 2009; Richardson et al., 2007; Schmidt & O'Brien, 1997). However, slowdowns and intermittent phase locking around 0° occurred during the final race, showing that the two

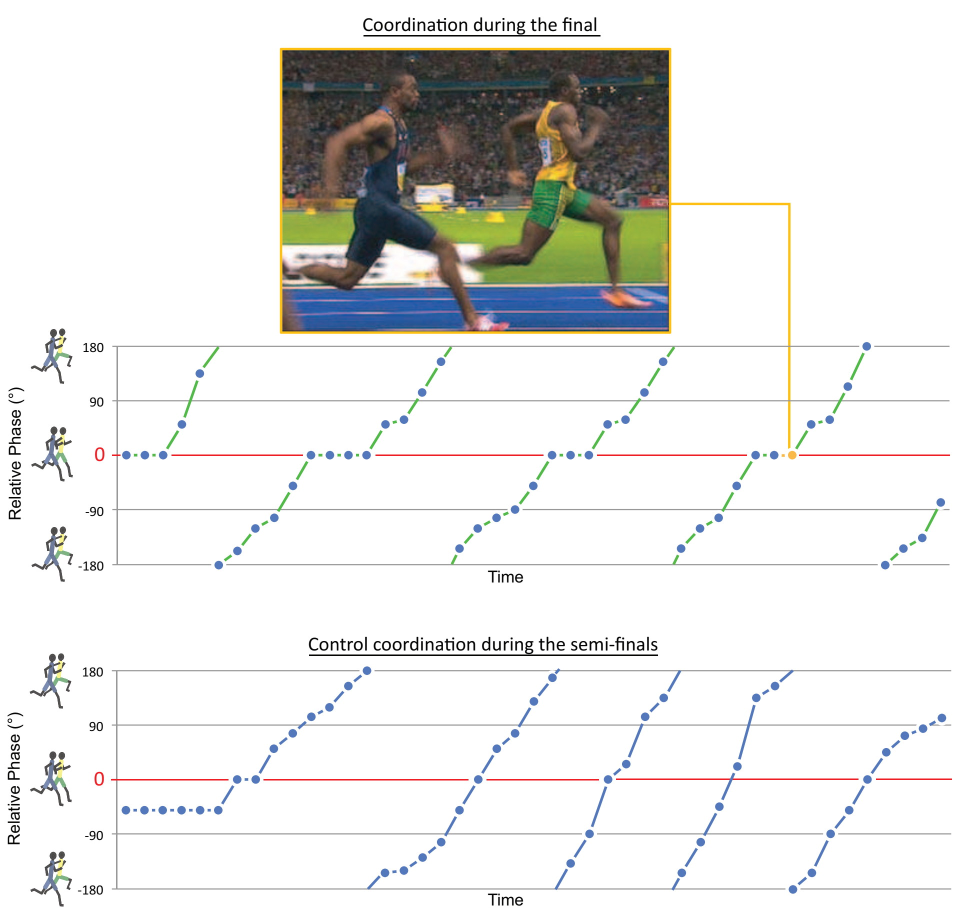

Figure 1. The graphic represents the computed relative phases between the steps of Usain Bolt and Tyson Gay at the 100-m final (green [dark gray]) and semifinals (blue [black]) of the 12th IAAF World Championship in Athletics (Berlin, 2009). The relative phases continuously drift as expected due to the difference between the natural stride frequencies of the two sprinters, but with slowdowns and phase locking occurring around 0° during the final. Such slowdowns (not observed for the control semifinals relative phase when the two sprinters ran separately), indicate that Usain Bolt and Tyson Gay spontaneously synchronized, as illustrated in the picture taken approximately at the time 7.79 s, few time before their steps # 34 and # 37, respectively. See the online article for the color version of this figure.

sprinters exhibited short periods of synchronized behavior. Such slowdowns or synchronized behavior around 0° were not observed for the control semifinal, revealing that it is the perceptual coupling that linked the two sprinters during the final that led to synchronization (Richardson et al., 2007; Tognoli et al., 2007; Schmidt & O'Brien, 1997). The examination of the relative phase distributions presented in Figure 2 confirmed this result. The highest percentage of occurrence was observed for the 0° phase region for the final race and this percentage was the only one higher than the significance threshold, further supporting that this synchronization did not occur by chance.

The results therefore demonstrate that Usain Bolt and Tyson Gay perceptually coupled to each other during the final spontaneously, and intermittently synchronized their steps. Although it is not possible to determine exactly how this synchronization modulated their preferred strides, the frequency and amplitude exhibited by the two sprinters would have been different if they had run alone or with someone else (Marmelat et al., 2014; Nessler & Gilliland, 2009; Schmidt & Richardson, 2008; van Ulzen et al., 2008). The synchronization that occurred during the final implies that Usain Bolt slightly increased his step frequency and/or that Tyson Gay slightly decreased his step frequency (Nessler & Gilliland, 2009; Schmidt & Richardson, 2008; van Ulzen et al., 2008). Given that movement frequency and amplitude of oscillatory behaviors are closely linked to each other (i.e., faster frequencies typically correspond to small amplitudes of movement and vice versa; Pikovsky et al., 2001), it is also likely that the synchronization led to a decrease of Usain Bolt's stride length and/or an increase of Tyson Gay's stride length. Accordingly, we think it is reasonable to conclude that the synchronization between the two sprinters might have influenced how fast they ran. One might initially assume that such external influence on the two sprinters' behaviors would be detrimental, in that it might affect the accuracy or efficiency of the movements performed and result in slower performance. However, the inverse is also possible. Indeed, a number of previous studies have shown that the stability and efficiency of gait behavior can be enhanced when entrained to external rhythms (Hove, Suzuki, Uchitomi, Orimo, & Miyake, 2012; Hunt, McGrath, & Stergiou, 2014; Rhea, Kiefer, D'Andrea, Warren, & Aaron, 2014; Roerdink, Bank, Peper, & Beek, 2011; Roerdink, Lamoth, Kwakkel, Van Wieringen, & Beek, 2007). There is also recent research demonstrating that running behavior and performance can be enhanced by listening to auditory rhythms such as the beats of simple metronomes or music (Bacon, Myers, & Karageorghis, 2012; Karageorghis et al., 2009; Simpson & Karageorghis, 2006; Terry, Karageorghis, Saha, & D'Auria, 2012). Independent of its motivational aspects, music with prominent and consistent beat can also help to optimize running efficiency (Bood, Nijssen, van der Kamp, & Roerdink, 2013). Similar effects might occur with auditory rhythms produced by other people, and therefore, it remains possible that the synchronization enhanced the performance of Usain Bolt and/or Tyson Gay.

In line with this research, auditory information is likely to have supported the occurrence of interpersonal synchronization between the two sprinters during the final. That is, hearing each other's steps might have provided a coupling by which Usain Bolt and Tyson Gay spontaneously and intermittently synchronized their strides (Zivotofsky, Gruendlinger, & Hausdorff, 2012; Zivotofsky, & Hausdorff, 2007). It is possible that the synchronization might also have been supported by the exchange of visual movement information between the two sprinters. Supporting such a possibility are the numerous studies that have demonstrated the occur-

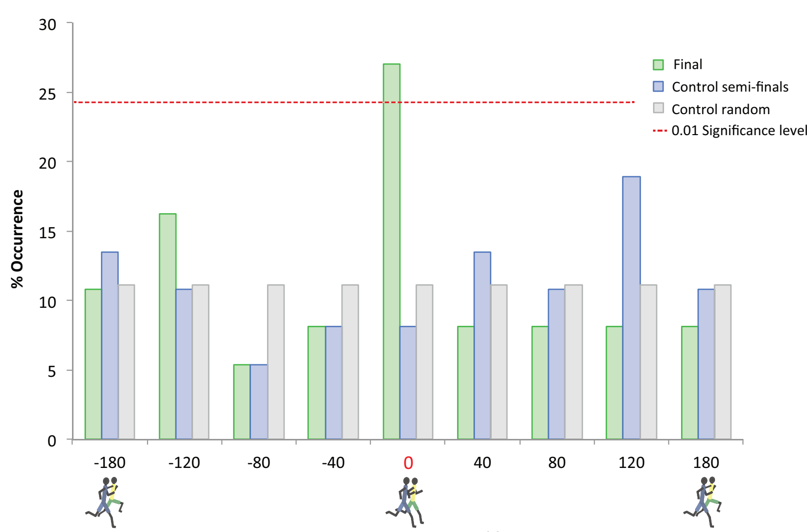

Figure 2. The graphic represents the distributions of the final (green [dark gray]) and control semifinals (blue [black]) relative phase angles. The third gray distribution corresponds to the average of the 100,000 relative phase distributions randomly generated. The percentage of occurrence for the 0° phase region of the final distribution is higher than the 0.01 significance threshold represented by the dashed red (black) line (corresponding to the 99,900th highest percentage of occurrence randomly generated), which shows that synchronization between Usain Bolt and Tyson Gay during the final did not occur by chance. See the online article for the color version of this figure.

rence of spontaneous movement entrainment between two or more individuals who are visually coupled, even only peripherally (Issartel et al., 2007; Richardson et al., 2007; Richardson, Marsh, & Schmidt, 2005; Schmidt & O'Brien, 1997; Tognoli et al., 2007). The availability of visual information might have strengthened the coupling between the two sprinters, and thus, the occurrence of longer periods of phase-locked strides. This possibility, however, raises questions about the directionality of the coupling between the two sprinters. Did Usain Bolt and Tyson Gay equally synchronize or did one of them synchronize more than the other? Indeed, slightly positioned behind Usain Bolt during the race, Tyson Gay had better access to visual movement information, and thus, might have been more likely to synchronize. The nature of the coupling and how synchronization might have enhanced or degraded the performance of Usain Bolt and Tyson Gay during this race will remain open questions but highlight new and promising future research directions with respect to understanding the effects of spontaneous motor synchronization in competitive sport.

More generally, these results demonstrate that even the most optimized and highly demanding individual motor skills can be modulated by the simple presence of other competitors through interpersonal synchronization processes, and that this can happen without the awareness of the athletes nor that of millions of spectators. These findings extend previous research by showing that the hard constraints of individual motor performance do not overwhelm the occurrence of spontaneous interpersonal synchronization. Certainly, the robustness of this synchronization processes and the degree to which it can explain the modifications in the behavioral performance of the athletes across different types of competitive sport requires further investigation. Nevertheless, knowing when to avoid or take advantage of such unintentional or spontaneous interpersonal movement synchronization might become an important factor in trying to improve the performance of elite athletes.

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