joint receptors (Turvey, 1996), is not affected, at least at this stage, by diabetic complications.

We consider that the notion of functional system (Gibson, 1966) should be stressed in order to apply the actual knowledge on dynamic touch and haptics in the re-mediation of the blind (Ananiev, Vekker, Lomov & Iarmolenko, 1967) and, specifically, the late blind diabetics that extremely challenge rehabilitation professionals (Harley, Pichert & Morrison, 1985).

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Studies in Perception and Action VI
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Effects of Asymmetry on Automaticity and Adaptability in Adult Walking

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Mature walking is both extremely automatic and extremely adaptable. On the one hand, walking is characterized by cyclical, stereotyped movement patterns. Walkers maintain a consistent, symmetrical relationship in the distance and timing of leg movements from step to step. On the other hand, automaticity of gait patterns does not imply rigidity. Walkers routinely show flexible adaptation of step length and step time to deal with changes in their bodies (e.g., carrying a load, coping with injury) and variations in the ground surface (e.g., slant, obstacles in the path).

Method

To examine the relationship between automaticity and adaptability, we attempted to disrupt the automatic aspects of gait. Fourteen healthy adults were instructed to walk normally in ten trials in each of four conditions. First, in the baseline condition, participants walked in two normal shoes to provide measures of their normal gait. Second, in the platform condition, we artificially lengthened one of participants' legs with a 4 cm platform shoe to observe the immediate effects of asymmetrical body dimensions on symmetry of leg movements. Such a large discrepancy in leg length is clinically relevant. Patients typically adopt altered gait patterns in an attempt to correct the asymmetry: toe-walking on the short leg, abducting the hip and swinging the long leg to the side, "Groucho walking" on the long leg by keeping the knee bent when the long leg is on the ground, etc. (Song, Halliday, & Little, 1997; Vogel, 1984). Third, in the practice condition, participants walked around the laboratory for 15 minutes and then demonstrated the effects of practice in the platform shoe. Finally, in the recalibration condition, we assessed possible carry-over effects from the platform shoe conditions and the immediate effects of readjusting to normal leg length. All test trials were conducted on a 366 cm long Gaitrite gaitmat (a pressure sensitive pad that records spatial and temporal footfall measures at 38 Hz with spatial resolution to 1.27 cm). The gaitmat yielded measures of step length (distance between consecutive foot falls) and step time (time between consecutive foot falls).

We reasoned that automaticity might come at a cost for adaptability and vice versa. In the worst-case scenario, continued adherence to an over-practiced movement pattern might cause participants to trip or stumble in their platform shoe. Less dramatically, attempting to maintain automatized leg movements might result in energetically costly, asymmetrical gait patterns, such as limping. Alternatively, relaxing automaticity to cope with asymmetrical leg length might allow participants to walk without mishaps. However, the cost of adaptability might be increased variability from step to step.

Results and Discussion

Surprisingly, in the first baseline condition, most participants showed evidence of small but consistent asymmetry in step length and step time. Even before the artificial lengthening of one of participants' legs, individual t-tests (all *p*s < .05) revealed that 4 participants displayed symmetrical step length, 3 took longer steps with the leg which would wear the platform shoe, and 7 took longer steps with the leg which would wear the normal shoe. Six participants displayed symmetrical step time, 4 took slower steps with the leg which would wear the platform shoe, and 4 took longer steps with the leg which would wear the normal shoe. Figure 1 shows the natural discrepancy between legs in the baseline condition for step length and step time.

In the platform shoe conditions, participants showed a trade-off between automaticity and adaptability. No one tripped or stumbled. No one adopted an idiosyncratic or altered gait strategy such as toe-walking, hip abduction, or Groucho walking. Every participant displayed more energetically costly gait patterns as a result of their longer leg and the platform affected participants similarly, regardless of their baseline leg dominance. Immediately after introduction of the platform shoe in Condition 2, they limped, and continued to do so to the same extent after extended practice in Condition 3. Relative to baseline, the long leg traveled a longer distance along the floor resulting in increased step length (Figure 1A) and took less time to complete its cycle resulting in decreased step time (Figure 1B). Conversely, the short leg traveled a shorter distance along the floor and took more time to complete its step cycle. Limping was quite pronounced, accounting for an average of 7.16% of participants' normal step length and 6.64% of their normal step time. Leg dominance in baseline affected only the initial difference between legs, not the pattern of divergence between legs or the magnitude of the change in the platform shoe conditions. Repeated measures ANOVA on the difference between step lengths in the leg wearing the platform shoe and the leg wearing the normal shoe showed a main effect for condition (*F*(3, 33) = 89.39, *p* < .001) and a main effect for baseline leg dominance (*F*(2, 11) = 9.39, *p* < .004). Likewise, repeated measures ANOVA on the difference between step times in the two legs showed a main effect for condition (*F*(3, 33) = 40.13, *p* < .001) and a main effect for baseline leg dominance (*F*(2, 11) = 7.61, *p* < .008). In addition to pronounced limping, participants' gait patterns showed yet another cost of adapting to asymmetrical leg length. Within trial variability increased in the platform shoe conditions for step length (*F*(3, 33) = 26.98, *p* < .001) and step time (*F*(3, 33) = 7.99, *p* < .001).

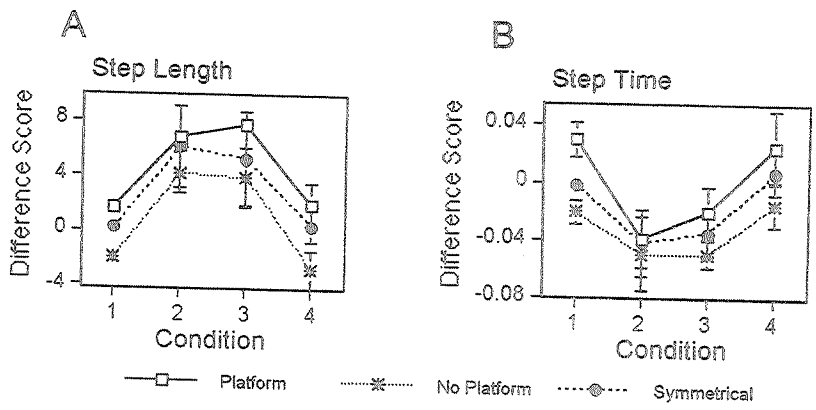

Figure 1. Difference scores between the leg which wore the platform shoe and the leg which wore the normal shoe for step length (A) and step time (B) in the four conditions (1=baseline, 2=platform, 3=practice, 4=recalibration). Error bars represent standard deviations.

Automaticity of joint angles and movement trajectories maintains consistency in walking. Adherence to automatized joint angles may explain why participants displayed a common diverging gait pattern between long and short legs. Step length increased in the long leg because it traveled a farther horizontal distance in the air when it was extended. For the same reason, taller people take longer steps than shorter people when both groups straighten their knee to the same extent. A similar explanation can account for step time. The long leg took more time to extend while supporting the body; as it straightened the pivot of the short leg was artificially raised. The short leg took more time to complete its cycle because the foot had to wait in mid-air for the long leg to completely extend; then it had to travel a longer vertical distance in the air before heel contact. Our results suggest that there is a reciprocal relationship between automaticity and adaptability such that change in one factor comes at a cost to the other.

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Asymmetry in Bimanual Coordination in Parkinson's Disease

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In Parkinson's Disease (PD), symptoms such as bradykinesia, rigidity and tremor are often asymmetrically distributed over the left and right side of the body. This pronounced asymmetry may have a disruptive effect on coordination in interaction with other intrinsic (e.g., natural hand preference) and task asymmetries (e.g., hand role and focus of attention). On the other hand, a 'bad side' implicates there is a 'good side' as well, that may adapt in order to generate a specific stable coordination pattern.

We investigated the influence of an asymmetric pathology in interaction with symmetrical or asymmetrical visual feedback of the tapping fingers on symmetric (antiphase) and asymmetric (left leading gallop and right leading gallop) coordination tasks.

In healthy adults, a subtle asymmetry is visible in their preference of one hand over the other in everyday tasks and in the difference in performance between the hands (Peters, 1994). Asymmetric attention has been shown to modulate the stability and asymmetry of coordination in symmetric oscillatory tasks (Amazeen, Amazeen, Treffner & Turvey, 1997). In asymmetric bimanual tasks, the asymmetry between the hands is less subtle. In multifrequency tapping for instance, coordination often breaks down when subjects are asked to tap the faster beat with their non-preferred hand instead of their preferred hand (Peters, 1994). Also, the bimanual gallop is most stable and reported 'easier' when the preferred hand is also the leading hand (Verheul & Geuze, 2000).

From a dynamic systems perspective, both the intrinsic dynamics and the ad hoc context contribute to the performance. If the asymmetry in PD patients can be regarded an intrinsic asymmetry with similar but stronger effects than handedness, then the gallop with the non-affected hand leading should be more stable than the gallop with the affected hand